BRAIN.

PART II., 1909.

Original Articles and Clinical Cases.

ON THE STRUCTURE AND FUNCTIONAL RELATIONS OF THE OPTIC THALAMUS.

BY ERNEST SACHS, A.B., M.D., OF NEW YORK

From Sir Victor Horsley's Laboratory in the Department of Pathological Chemistry in University College, London.

SYNOPSIS.

INTRODUCTION.
HISTORICAL.
Physiology.
Anatomy.
Thalamic Nuclei.
Fibres between Thalamic Nuclei.
Thalami-cortical Fibres.
Cortici-thalamic Fibres.
Descending Thalami-fugal Fibres.
DESIGN OF RESEARCH.
METHODS AND TECHNIQUE.
POSITION OF THALAMIC NUCLEI.
RESULTS OF CORTICAL LESIONS.
Pallio-tectal System.
ELECTROLYTIC LESIONS IN THE THALAMUS.
Nucleus Anterior.
Nucleus Medius.
Nucleus Lateralis.
Centre Median and Nucleus Arcuatus.
Hypothalamus.
STIMULATION EXPERIMENTS.
SYMPTOMS.
SUMMARY.

AT the very outset I wish to express my deep gratitude to Sir Victor Horsley for the privilege of working in his laboratory, for his innumerable kindnesses, and for the benefit of his many valuable suggestions, frank criticism, and unerring judgment. He suggested the subject and

method of the investigation and co-operated in the performance of the experiments and revision of the preparations. I am also much indebted to Dr. R. H. Clarke for his ever-ready assistance and advice, as well as for the use of his stereotaxic instrument. To Miss E. Clarke's unflagging interest and careful assistance the results obtained are in great part due.

The optic thalamus, with its adjacent ganglia, has been the subject of numerous investigations during the past thirty years. These have dealt with the anatomical as well as the physiological side of the question. There still remain, however, many obscure points which make this a profitable field, and particularly for a new method such as has been employed for the present work.

Historical.

The very comprehensive monograph by Roussy [135] on the optic thalamus, published during the past year, deals with the historical survey of our present state of knowledge so thoroughly that, for the sake of brevity, but a general outline of methods and results of past work will be given here.

Prior to the work of Nothnagel [115] and Meynert [104] very crude experiments were performed on the basal ganglia by Luys [95], Schiff [139], Burdach [26], Magendie [96], Serres and Loustan [143], and others.

With Nothnagel began the period of studying this region by means of localized lesions, and that plan has been followed for the most part up to the present day, though more refined methods have been employed.

These methods may be grouped under three headings:—

First.—The injection of fluids (Nothnagel and Fournié) [58].

Second.—Incisions or destruction by some mechanical means. Of these, that employed originally by Veysierre [153] and later by Probst [123], viz., a trochar containing a hidden wire which could be pushed forward to produce the lesion, was the most generally used. By the mechanical method results were obtained by Ferrier and Turner [49], Bechterew [8], Mislawski [13], Ernst [47], Probst [123], Ziehen [159], Ott [119], and others.

Third.—Electrolytic lesions, first used by Sellier and Verger [140], then by Roussy [135], and Horsley and Clarke [75], in their work on the cerebellum.

Physiology.

The earliest observers—Magendie [96], Flourens [54], and Schiff [139]—were of the opinion that the thalamus was the centre for voluntary motor functions, the last named even believing it controlled intestinal movements. These early investigators described "mouvements de manège" as characteristic of thalamic lesions.

Carpenter, in 1851, and after him Meynert [104], in the Seventies, however, expressed the following view: "The optic thalamus is the centre for unconscious reflex movements resulting from peripheral stimuli, and from it these are carried to the cortex, producing images of these movements, which then are the basis for voluntary movements." Nothnagel [116] and Ferrier [48] believed it was a sensory station between the lower centres and the cortex. Carville and Duret [31] held similar views. There followed then numerous investigations by Bechterew and his pupils—Mislawski [15-17], Ostankow, Irwanow [77], and Ernst [47]. In these experiments the cortex was removed in part and the various regions stimulated with the faradic current. They described numerous centres in the thalamus controlling various functions, movements of the stomach and intestine, bladder, vagina and rectum, also lachrymation and a screaming centre, described by Irwanow, referred to by Bechterew as a centre where stimulation produced "Geschrei wie es auf Schmerz auftritt." These investigations have, as far as can be discovered, never been confirmed.

Thiele [149] obtained locomotor movements of the limbs on stimulating the cut surface of the posterior part of the thalamus.

Hale White [68] and Ott [119] found changes in temperature associated with thalamic lesions, and the latter also noted changes in blood-pressure. Christiani described a mastication centre.

Sellier and Verger [140] found hemianæsthesia in their animals after thalamic lesions, but advanced the important conclusion that visual symptoms were not obtained from the anterior and lateral parts of the thalamus, but only from the posterior portions. Up to this time ocular symptoms, especially hemianopsia, had been described as a symptom of thalamic lesions irrespective of the region injured.

Von Monakow [107], in his elaborate monograph—the important anatomical features in which will be taken up later—regards the thalamus as wholly a sensory centre.

Probst [129], in one experiment, found slight sensory changes—hemianopsia and a paresis of the limbs—on the same side, as well as a loss of the sense of position of the extremities.

Prus [130] dividing the thalamus arbitrarily into four parts—anterior, middle, central, and lateral—stimulated each *after removing the cortex*, and concluded that the thalamus contained centres for respiration, pulse-rate, blood-pressure, motor movements, and particularly mimicry and anger. It seems an obvious criticism of these experiments that the large area of cut nerve fibres exposed after the cortex is removed may be a cause for some, at least, of the phenomena observed quite irrespective of the stimulation.

Roussy [135], after thalamic lesions, observed :—

(1) Mouvements de manège; (2) superficial sensory changes, hypoæsthesia, hypoalgesia, hypothermæsthesia; (3) deep sensory loss, evident by the loss of the sense of position of the limbs, and in the case of a monkey by a tendency to use the unaffected upper extremity more; (4) unilateral loss of hearing (in two animals).

Anatomy.

On this phase of the subject, among the most important studies are those of Kölliker [83], Burdach [26], Edinger [45], Nissl [114], v. Monakow [109], Münzer and Wiener, Ramon y Cajal [28], Bechterew [12], and Probst [129].

We are concerned here, firstly, with the nuclei of the thalamus and their connections with one another; secondly, the thalami-cortical paths; thirdly, the cortici-thalamic; and fourthly, the thalami-spinal paths, if such exist.

Thalamic Nuclei.

The nuclei of the thalamus have been variously classified.

The simplest is that given by Kölliker [83], Obersteiner [117], and Marburg [98]. According to these observers the thalamus is divided into the following nuclei :—

(1) Nucleus anterior or tuberculum anterior.
(2) Nuclei disseminati.
(3) Nucleus medius.
(4) Nucleus lateralis.
(5) Nucleus lateralis ventralis.
(6) Centre median.
(7) Nucleus arcuatus.
(8) Corpus geniculatum externum.
(9) Corpus geniculatum internum.

Nissl [114] describes nineteen nuclei as follows :—

(I.) Anterior nucleus: (1) anterior dorsal; (2) anterior ventral; (*a*) dorso-medial, (*b*) ventro-lateral.

(II.) Anterior median nucleus.

(III.) Median middle nucleus.

(IV.) Ventral nucleus of the "Gitterschichte."

(V.) Lateral nucleus of the "Gitterschichte."

(VI.) Dorsal nucleus of the "Gitterschichte."

(VII.) Nucleus of the median line. (This nucleus is split into a dorsal and ventral part by the median middle nucleus.)

(VIII.) Lateral nucleus (large-celled nucleus).

(IX.) Median posterior nucleus.

(X.) Ventral nucleus: (1) ventral lateral; (2) ventral dorsal; (3) ventral median.

(XI.) Lateral posterior nucleus.

(XII.) Ganglion habenula: (1) lateral; (2) median.

(XIII.) Posterior nucleus.

Von Monakow [107], from a large series of experiments in which he used for the most part Gudden's degeneration method, makes the following classification:—

(I.) Tuberculum anterior: (1) anterior *a*; (2) anterior *b*; (3) anterior *c*.

(II.) Lateral nucleus: (1) lateral *a*; (2) lateral *b*.

(III.) Median nucleus: (1) median *a* (magno cellularis); (2) median *b*; (3) median *c*.

(IV.) Ventral nucleus: (1) ventral *a*; (2) ventral *b*; (3) ventral *c*; (4) ventral anterior.

(V.) Posterior nucleus.

Von Monakow does not, however, consider several points of experimental and pathological import, which must be fully discussed before one can positively connect any one nucleus with a particular part of the cortex. In his investigations large areas of cortex were excised, and the atrophy of the thalamic nuclei was studied by Gudden's method. In excising large areas of cortex there must necessarily be considerable thrombosis of the large arteries, and as a result a part of the blood supply to the thalamus may have been interfered with. The atrophy observed may have resulted in part from this cause. In support of this criticism Beevor, in his recent paper on the blood-supply of the human brain, showed that the same vessels supply the thalamus as supply the superior and middle frontal convolutions.

Furthermore, by destroying a portion of cortex from which fibres

arise which only pass through the thalamus, the resulting atrophy of these fibres may produce the appearance of shrinkage of the nuclei without complete disappearance. This, in fact, occurred in some of the nuclei in which changes were described.

Ramon y Cajal [28] uses the following classification of the thalamic nuclei. He conceives the nuclei as divided into three series :—

(I.) Lateral series : (1) external geniculate ; (2) internal geniculate; (3) pulvinar ; (4) radiate nucleus (lattice nucleus of Nissl).

(II.) Intermediate series : (1) angular ; (2) dorsal ; (3) main sensory nucleus (Foco sensitivo), with its accessory or semilunar nuclei ; (4) posterior nucleus.

(III.) Median series : (1) median nucleus ; (2) commissural nuclei ; (3) middle nucleus ; (4) internal nucleus ; (5) ganglion habenula.

Mann, in a preliminary paper, distinguished the nuclei as follows : He adopted primarily the old division into a dorsal and ventral portion. The dorsal he again subdivided into a dorsal and ventral area. The portion bounded by the surface looking towards the middle line he called the ventricular third, the lateral aspect the lateral third. Between these two lies the subventricular third. He worked on the Marmoset monkey, and recognized the following nuclei :—

(I.) Anterior nucleus : No. 1 *a*, No. 1 *b*.

(II.) Ventricular nucleus : No. 2 *a*, No. 2 *b*, No. 2 *c*.

(III.) No. 3 *A*, No. 3 *B*, 3 *B a*, 3 *B b* (3 *B b z*, 3 *B b x*), 3 *B c*.

(IV.) Posterior nucleus : No. 4 *A*, No. 4 *B*.

(V.) Ganglion habenulæ : No. 5 *a*, No. 5 *b*.

(VI.) External geniculate body : No. 6 *a*, No. 6 *b*.

(VII.) Internal geniculate body : No. 7 *a*, No. 7 *b*.

(VIII.) Pineal body.

(IX.) The retinæ.

(X.) Reticular nuclei (these are subnuclei) : No. 9 *a*, No. 9 *b*, No. 9 *c*.

(XI.) Ventral nucleus : zone *a*, zone *b*, zone *c*.

Without further detail it is difficult to compare the nuclei thus designated with those found by other observers.

Recently, while in Professor Obersteiner's laboratory in Vienna, I examined thirty-four mammalian brains (marsupials to man), comparing their optic thalami. This study, together with the brains of the cats and monkeys used in the present investigations, have led me to adopt, at Sir V. Horsley's suggestion, the following classification of the thalamic nuclei until the precise connections of each part with the rest of the brain are determined. It corresponds very closely to the

original description by Burdach [26], and at least for the results recorded below seems most practical :—

Nucleus anterior.
Nucleus medius.
Nucleus lateralis (dorsal portion, middle portion, ventral portion).
Nucleus ventralis.
Centre median.
Nucleus arcuatus.
Pulvinar.

The anterior of these are well seen in fig. 28.

Fibres Between the Intrinsic Thalamic Nuclei.

As to the intrinsic fibres between the thalamic nuclei, I have been unable to find any observations, except the one conjecture by

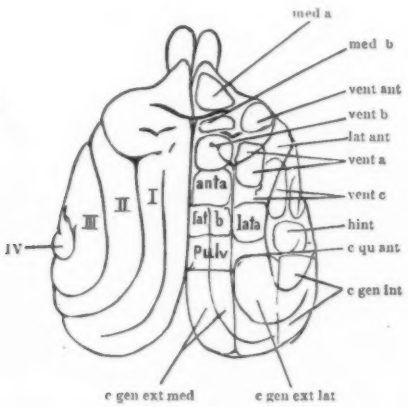


FIG. 1.

Probst [129] that the nucleus anterior sends its fibres to the caudate nucleus and Lewandowsky's [88] belief that there is a connection between the nucleus anterior and the corpus Luysii.

This point is discussed under the description of the lesions.

Thalami-cortical Fibres.

Thalami-cortical fibres have been described by Monakow [109], M. and Mme. Dejerine [40], Van Gehuchten [62], Lewandowsky [88], Roussy [135], and Probst [129].

Von Monakow [107], using Gudden's method, allotted certain thalamic nuclei to definite parts of the cortex, and believed that most of the connecting fibres were thalami-cortical. The accompanying drawing (fig. 1) from his article shows these connections. It has been pointed out why the results obtained by this method cannot be accepted as completely satisfactory.

Dejerine [40], in 1901, spoke of thalami-cortical fibres, but did not describe from which part of the thalamus they arose, nor to which part they were distributed. He believed them to be equal in number to the cortici-thalamic fibres.

Van Gehuchten [62], in 1906, said the thalami-cortical fibres had their origin from the lateral nucleus of the thalamus, and that it was supposed that they ended in the central convolutions and paracentral lobule mostly in the post-central convolution and the precentral convolution immediately adjacent.

Lewandowsky [88], in 1907, also spoke of thalami-cortical fibres, but gave no more detailed account of their origin or distribution.

Probst [129], in one case on a monkey, severely injured the capsule near the thalamus, and, as he found degeneration in the cortex, concluded there must be thalami-cortical fibres. He ignored the fact that fibres degenerating from such an extensive lesion may have had some other origin and considered that the accompanying injury to the corpus callosum was not responsible for the degeneration observed in the cortex. Probably some of the fibres were in fact thalami-cortical, but the evidence offered was not adequate.

In Roussy's [135] experiment on the monkey the capsule was not injured, but the injury to the corpus callosum, cingulum, and the slight injury to the superior frontal convolution, might be responsible for some of the degeneration he observed, as he himself suggests. He described numerous fibres passing to the frontal lobes (radiations thalamiques anterieures), and radiations thalamiques moyennes (fronto-parietales), which go to the pre- and post-central gyri and some to the lenticular nucleus.

The frontal fibres he believed came from the nucleus anterior and internal nucleus, while the fronto-parietal fibres came from the "external" (lateral) nucleus. He also found fibres going to the first temporal convolution and to the parieto-occipital region from the posterior part of the thalamus. He observed no connections between the thalamus and subthalamic body. He saw fibres going to the red nucleus, but was not certain whether their condition was genuine degeneration or due to indirect Wallerian degeneration. He observed no fibres going to the cord.

Cortici-thalamic Fibres.

It has been shown by Flechsig [51], Bechterew [12], Edinger [45], Dejerine [40], Kölliker [83], and others, that there probably exist cortici-thalamic fibres. This has been emphatically denied by Lewandowsky [88], and v. Monakow [109] believed they were very few. Van Gehuchten believes they exist. Dejerine, from observations with the Marchi as well as the Weigert method in cases of lesions of the hemispheres in man, described them as going to the external, internal and anterior nuclei of the thalamus, also to the "zone réticulée," pulvinar, ventral part of external nucleus and centre median of Luys.

Thalami-striate Fibres.

Fibres between the thalamus, corpus striatum, and subthalamic region have also been described, notably by Edinger and Dejerine, but, owing to the difficulties underlying their demonstration, little is known in mammals beyond their mere existence.

Descending Thalami-fugal Fibres.

Investigators are divided into two camps as to descending or thalami-fugal connections. One, headed by Bechterew, his pupils, and Wallenberg, believe that there are descending tracts to the cord. The most recent publication on the subject is by one of his pupils, Ernst [47]. This work, being in Russian, has probably not received full recognition.

His conclusions are as follows:—

(1) Degeneration to the medulla occurs from lesions in the posterior part of the thalamus only.

(2) The nucleus anterior and the anterior and middle parts of the thalamus send no descending fibres.

(3) After injury to the posterior and inner part of the thalamus descending degeneration to the external part of the anterior colliculus and to the nucleus ruber occurs.

(4) Two tracts were traced down to the medulla. After injury to Monakow's nuclei med. *a* and vent. *b* one tract runs along the outer side of the fasciculus longitudinalis posterior and ends in the nucleus of the formatio reticularis. The other ends in the nucleus reticularis tegmenti.

Opposed to Bechterew's [8] views are van Gehuchten [62], Dejerine [40], Probst [123], and Roussy [135]. They believe that no descending tracts arise from the thalamus itself.

The explanation of this apparent diversity is due to the lesions employed having been so gross that no accurate conclusion could be drawn as regards the precise source of any descending degeneration. The reader is referred to p. 151, &c., for the facts which fully explain the positive results obtained by Ernst.

Design of Present Research.

From the foregoing historical account it will be seen that the fundamental problems requiring solution are :—

(1) The arrangement and relations of the intrinsic nuclei of the thalamus.

(2) The existence, if any, and distribution in the thalamus of cortico-thalamic tracts.

(3) The distribution and origin of fibre-tracts leaving the thalamus.

Without anticipating the detailed summary of results given on p. 180 at the end of this paper, it should be stated at once that the present research has definitely established the correctness of the old view first proposed by Burdach, and for many years the solely accepted mode of regarding the thalamus—namely, that it is essentially composed of three parts: (1) an external lying between the internal capsule and the lamina interna; (2) an internal between the lamina and the median line; (3) an anterior corresponding to the nucleus anterior.

Methods and Technique.

For the present investigation there were used sixty-one monkeys (*Macacus rhesus*) and thirty-three cats.

The experiments will best be arranged as follows, in three groups. They were all performed by Sir Victor Horsley or myself.

Group I.—Localized lesions of the cortex cerebri and subsequent anatomical investigation of the cortici-thalamic fibres.

Group II.—Localized lesions of the thalamus and subsequent anatomical investigation of the thalami-cortical and other tracts of fibres associated with the lesion.

Group III.—Phenomena observed on electrical excitation of the thalamus and its neighbourhood.

The animals were all anæsthetised with chloroform or ether. The animals in the first two groups were operated upon under strict aseptic precautions, kept alive eighteen to twenty-one days, and then killed

with an overdose of ether or chloroform, while those in the third group were killed while still under anæsthesia.

Group I.

The first group consisted of twenty-four cats and thirteen monkeys. Of these a certain number had to be discarded, several because they died of shock and hæmorrhage, several monkeys because they died of diarrhœa before degenerations could be studied, and a considerable number because of indifferent penetration by osmic acid, and a few because the lesions were not in the desired region. There remain to report in this group, therefore, nine cats and ten monkeys. In these eighteen animals very small areas of cortex were destroyed with concentrated nitric acid. The procedure of necrosis is one that has been used before by various observers, by whom, however, alkalies have been usually employed. A small brush with glass bristles on which all but about twenty bristles had been removed was used. This was sterilized and dried, and then dipped into nitric acid. All excess was shaken off and the cortex to be destroyed then painted with the acid. It is well to dry the cortex with small cotton pledgets just before applying the acid, so that it does not spread. As soon as the cortex is whitened, warm saturated bicarbonate of soda solution is poured over it to neutralize any excess of acid. With a little practice extremely small lesions can be made. It is important not to let the acid touch any large vessels, as the ensuing thrombosis produces a larger area of softening. The character of these lesions is shown in fig. 9. The slight depth to which the acid penetrates is shown in the figure. Later several lesions were made with a galvano-cautery, and this method is more satisfactory in that its lesions may be still more accurately defined. This series provided material for study of the cortici-thalamic fibres.

Group II.

The second group contained thirty-five monkeys and nine cats. Several monkeys had to be discarded—four because the lesions were too high and not in the thalamus, two because they died of diarrhœa, one because of poor osmic penetration, and one which became infected; five cats had to be discarded because they died of shock. There remained to study twenty-seven monkeys and four cats. Here the electrolytic method of Sellier and Verger [140] was made use of. In order to produce minute electrolytic lesions at known points in the thalamus, Clarke's stereotaxic instrument was used. This instrument

has been recently described in great detail by Horsley and Clarke [75] in their accounts of experiments on the cerebellum. To produce lesions in the thalamus a series of ten animals was first prepared in whom the needle was introduced through the vertex to the frontal region. This was the line of approach used by Probst and Roussy. In our earlier experiments we used the larger needles,[1] measuring 0·5-0·7 mm. in diameter, and sometimes the double needles, measuring 1·5-0·2 mm. in diameter. The lesion produced with the double needles is well shown in fig. 30. Even with the smallest needles, measuring 0·34 mm., there is sufficient injury to the corpus callosum to produce degeneration, which somewhat obscures the picture. It is this fact which probably accounts for the different results obtained by us compared with Probst and Roussy.

For this reason, in the last thirty-one experiments the lesions were made by introducing the needle horizontally through the occipital lobe as shown in fig. 36, where the needle track as well as the lesion is visible.

This produced some degeneration from the occipital lobes, but as the course of these fibres is well known through the work of Monakow [109], Cajal [28], Munk [111], Mott [110], and Probst [126], and can be readily distinguished from lesions in the other parts of the thalamus, it was of no significance. The primary object was to leave the frontal pre- and post-central gyri absolutely intact. As the needle was advanced millimetre by millimetre each point was stimulated with a faradic current, whose strength was regulated by a coil with the Kronecker graduation. These stimulations enable one to know where the needle point is, and, though unipolar, furnished valuable additional data to our stimulation experiments to be described under Group III. However, these unipolar stimulations must be used with considerable reserve for the reasons stated by Horsley and Clarke.

Group III.

In the third group there were thirteen monkeys. In this series the object was to stimulate systematically the thalamus millimetre by millimetre in each lamella to determine what phenomena were obtained at the various points. We have confined ourselves to recording movements of the voluntary musculature as well as movements of the pupil. The visceral phenomena, *i.e.*, blood-pressure changes (recorded by Prus [130] and Ott [119]), changes in temperature (described by

[1] See Clarke and Horsley [75].

Hale White [68]), and movements of the intestinal tract (described by Bechterew and others), we have not investigated, but on the facts of lachrymation, mastication, and vocalization, however, we have made observations, and believe that these phenomena admit of other explanations.

In these stimulations bipolar electrodes have been used throughout, for with one electrode in the brain and the other at an "indifferent" part of the body, untrustworthy results, due to escape of current, have been obtained. This question of unipolar and bipolar stimulation has been dealt with at length by Horsley and Clarke in their article in *Brain*, 1908. What they found in the case of the cerebellum has been confirmed by the present investigation of the thalamus, for with one electrode in the thalamus and the other on the trunk of the animal facial and neck movements were obtained by the excitation of points in the thalamus which yielded no observable muscular contractions at all when the bipolar needle was used.

Position of the Thalamic Nuclei.

On reference to Horsley and Clarke's paper, it will be found that, for purposes of orientation with Clarke's instrument, the brain is conceived as divided by three planes:—

The sagittal plane, which passes longitudinally between the two hemispheres.

The basal plane, whose four points are determined by the inferior margin of the bony orbits and the centres of the bony auditory meati. The horizontal plane employed for convenience as zero is parallel to this and 10 mm. higher in the average Rhesus monkey.

The frontal or inter-aural plane, perpendicular to the latter, passes through the centres of the two meatuses.

The plane sections of the encephalon, parallel to the sagittal plane, are spoken of as right or left lamella, I, II, III, &c., according to their distance in millimetres from the sagittal (zero) plane.

The height above or below the horizontal plane is designated in letters—thus, A = 1 mm. above or below the plane, B = 2 mm., &c. The numbers 1, 2, 3 designate the distance in millimetres in front of or behind the inter-aural plane.

These planes thus divide the brain into eight segments frontal (right or left) above the horizontal and in front of the inter-aural planes; temporal (right and left) below the horizontal and in front of the inter-aural planes; occipital (right and left) above the horizontal and behind the

inter-aural planes; cerebellar (right and left) below the horizontal and behind the inter-aural planes.

The optic thalamus in a normal Macacus rhesus lies entirely in the frontal and temporal segments with the exception of the posterior end of the pulvinar, which lies in the occipital segments.

The thalamic nuclei in a normal Rhesus, according to measurements from a number of our experiments, occupy the following position with reference to this nomenclature.

Nucleus anterior: Lamella II—IV, L—N, 8—12.

Nucleus medius: Lamella I—IV, G—L, 3—8.

Nucleus lateralis: Lamella IV—X, H—L, 4—13.

Nucleus ventralis: Lamella IV—VIII, E—H, 4—10.

Nucleus arcuatus and centre median; Lamella II—V, E—H, 4—6. Pulvinar: Lamella IV—X, anteriorly E—K, two behind inter-aural line to four in front; posteriorly C—G, two behind inter-aural line to four in front.

Results of Cortical Lesions.

On Table I are recorded the results of the cortical lesions and the cortici-thalamic paths thus displayed. From these certain definite conclusions have been reached. The general principle laid down by Monakow that the anterior part of the cortex cerebri is connected with the anterior portion of the thalamus, the middle part with the middle portion of the thalamus, and the occipital region with the posterior part or pulvinar, is in accord with the findings of all workers on this subject, notably Edinger [45], Cajal [28], Kölliker [83], van Gehuchten [62], Ferrier and Turner [49], and others.

Zuckerkandl, Edinger [45], Kölliker [83], and Dejerine [40] proved that the nucleus anterior belonged to the olfactory system, and Edinger [45], Hitzig [72], Munk [111], Ferrier and Turner [49], Probst [129] and others showed the intimate connection between the occipital lobe and the pulvinar.

It is with the middle portion that the present work is most concerned, and we have examined the conditions as they exist in the cat as a type of the Carnivora and in the Macacque monkey Macacus rhesus. As regards the cat, the relation of the thalamus to the gyrus pre- and post-crucialis, gyrus sigmoidalis, gyrus lateralis, and gyrus suprasylvius medius (cat), the Marchi method has yielded different results from those obtained by Monakow, who employed Gudden's method.

The fibres that actually end in the thalamus and arise from these regions all enter the nucleus lateralis (lateralis *a* and *b* of Monakow) or nucleus ventralis (ventralis *a*, ventralis anterior and ventralis *c* of Monakow). The various parts of the cortex cannot be said to be restrictedly connected with one or the other of these nuclei, though in every instance where the pre- and post-crucial gyri were involved the fibres passed to the nucleus lateralis and ventralis. In no instance have any fibres been seen going to the median nucleus or centre median. The lamina interna constitutes an absolute dividing line as regards the distribution of these fibres. This structure thus forms a most important line of demarcation both for the cortici-thalamic as well as thalami-cortical fibres, as will appear later (*see* fig. 2 *et seq.* Cat 99).

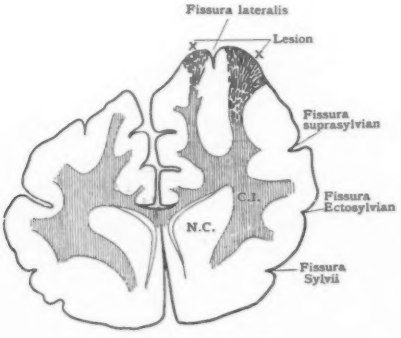


FIG. 2.—Cat 99 (I).

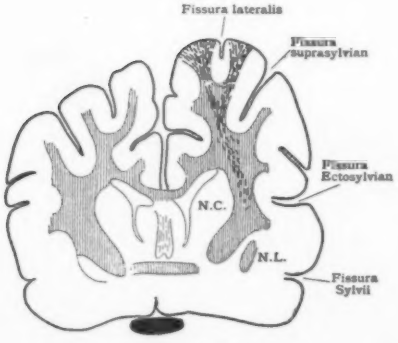


FIG. 3.—Cat 99 (II).

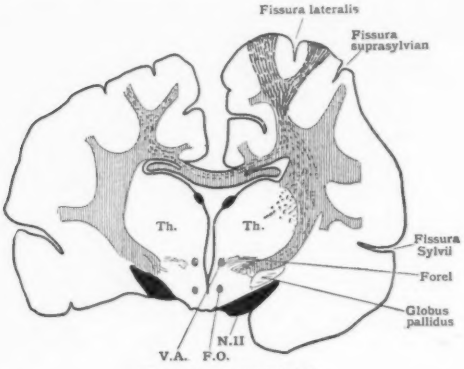


FIG. 4.—Cat 99 (III).

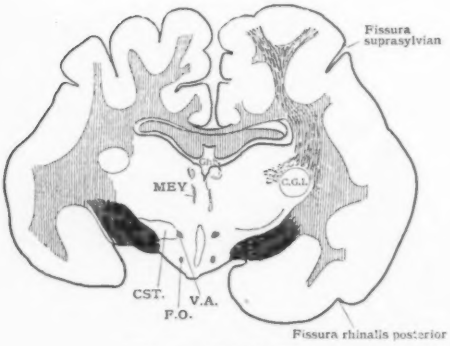


FIG. 5.—Cat 99 (IV).

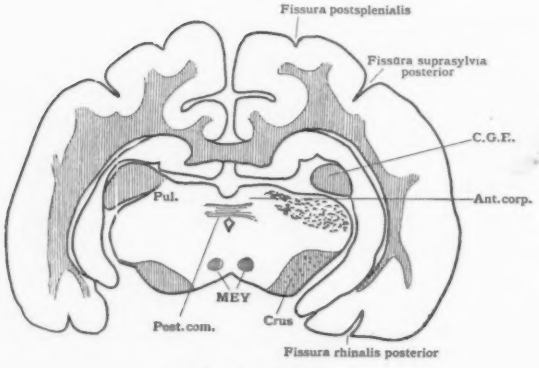


FIG. 6.—Cat 99 (V).

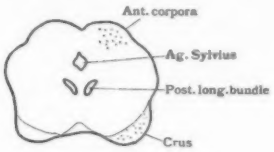


FIG. 7.—Cat 99 (VI).

FIG. 8.—Cat 99 (VII).

Besides the fibres ending in the thalamus there are also numerous pallio-tectal fibres, as described by Edinger, Beevor and Horsley. It is this group which must be distinguished carefully from the cortico-thalamic fibres.

On this point several of the animals throw some light, *i.e.*, whether pallio-tectal fibres come in larger numbers from one part of the cortex than another. In Cats 127, 131 and 283 the lesion was confined entirely or for the most part to the so-called motor area—*i.e.*, gyrus pre- and post-crucialis[1]—and gave rise to no pallio-tectal fibres, or at most extremely few, while from lesions in the suprasylvian or ectosylvian

FIG. 9.

Macacus rhesus. Marchi preparation, showing restricted character of the lesions employed in Table I.

R = Fissura centralis. G.Po.C. = Gyrus postcentralis.
G.Pr.C. = Gyrus precentralis. l. = lesion.
f.d.m. = degenerated pyramidal fibres.

[1] In the excellent text-book by Flatau and Jacobson [50] these gyri are spoken of as pre- and post-central. This attempt to correlate these gyri with the gyri of the same name in the human and anthropoid cortex is not satisfactorily proven. I therefore adhere to the old nomenclature.

regions many such fibres arise. The meaning of this fact seems perfectly evident, for from the pre- and post-crucial gyri no ocular or auditory stimuli can be elicited, while from the ectosylvian and suprasylvian gyri movements of eyes and ears are obtained upon faradic stimulations.

In the monkey (*Macacus rhesus*) only the pre-central and post-central gyri (*see* figs. 10 *et seq* and Table I) were explored by limited lesions with a view to determine their relation with the thalamus, and what difference, if any, existed between the thalamic fibres arising from the leg and arm area. In the monkey, as in the cat, the cortici-thalamic fibres were traced exclusively to the nucleus lateralis and nucleus lateralis (ventral part). No fibres passed beyond the lamina interna (*see* figs. 10 *et seq*)

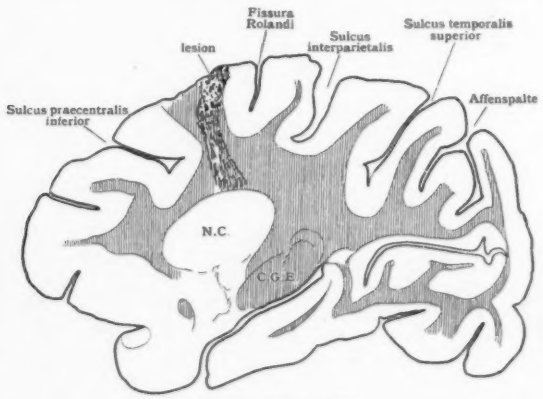


FIG. 10.—Rh. 143 (I).

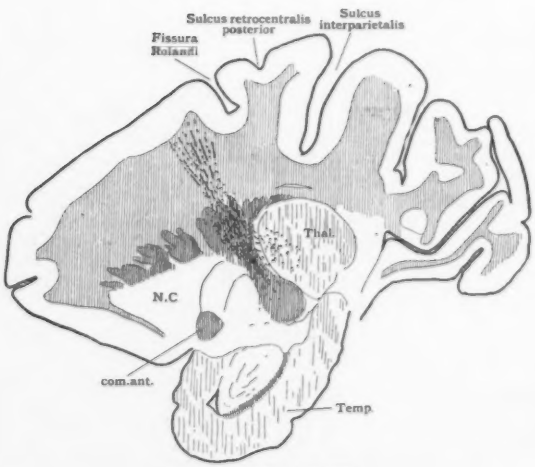


FIG. 11.—Rh. 143 (II).

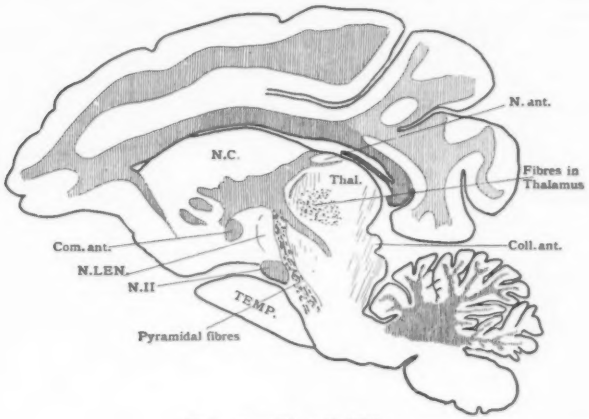


FIG. 12.—Rh. 143 (III).

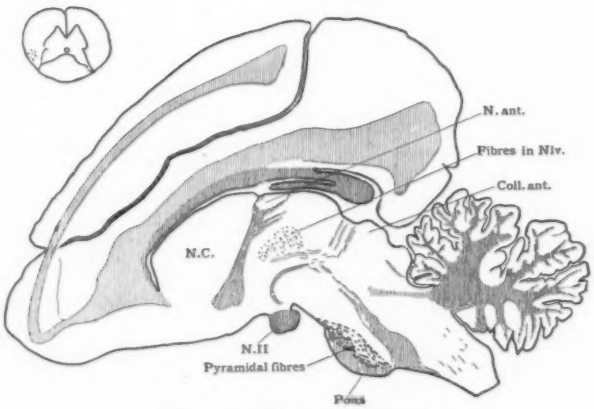


FIG. 13.—Rh. 143 (IV and V).

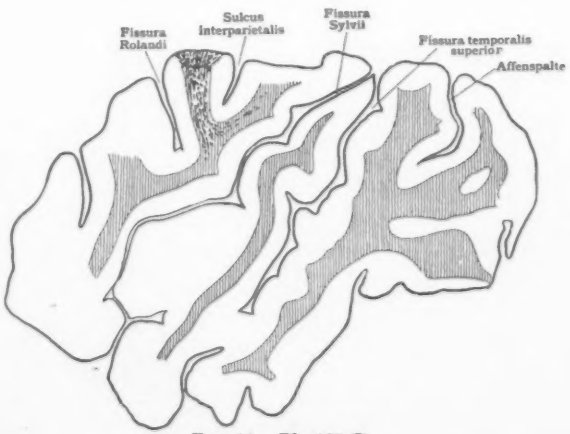


FIG. 14.—Rh. 165 (I).

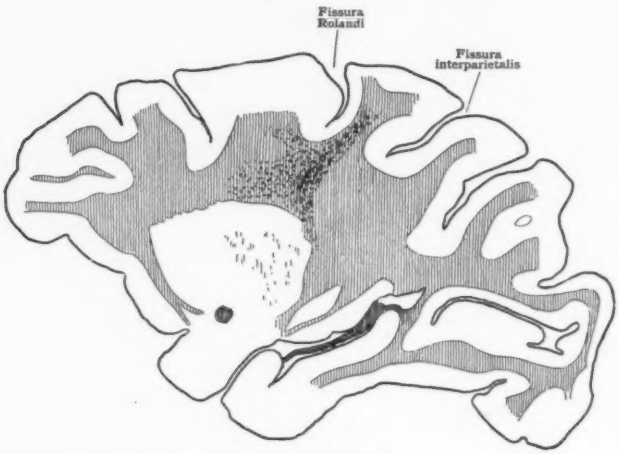


FIG. 15.—Rh. 165 (II).

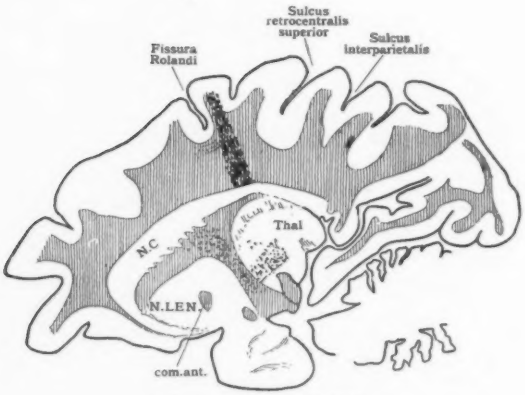


FIG. 16.—Rh. 165 (III).

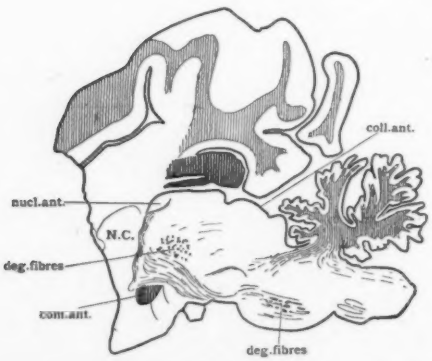


FIG. 17.—Rh. 165 (IV).

for the distribution of fibres from each of these gyri). In view of the controversy as to the functions of these two gyri the quantitative relation between the fibres going to the thalamus seemed of particular interest, as possibly throwing some light on this question. It must, of course, be remembered that in the Macacque brain the pre- and post-central gyri are not as definitely differentiated as in the anthropoids or man, yet the movements on cortical stimulation are all much more distinct pre-centrally. By destroying the pre-central arm or leg area we have endeavoured to find out whether these movements had also post-central localization, or were only due to spread of the current. As far as the thalamic distribution of cortici-thalamic fibres could be made out there seems to be no difference between these two gyri. No essential difference was observed between the distribution of the fibres from the leg and arm areas, but before an absolute opinion can be rendered on this point far more work is necessary than it has been possible to do here.

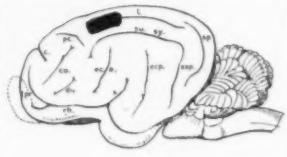
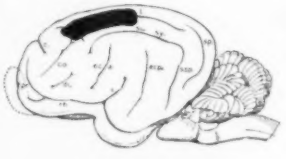
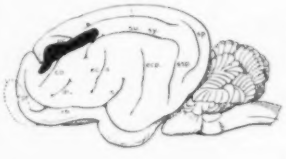
Pallio-tectal System.

The question of the structural changes set up by lesions in the thalamus has so far been discussed without reference to fibres which are transmitted through the thalamus, such as the system of fibres which directly connects the pallium with the tectum or corpora quadrigemina. These fibres, first observed by Edinger [43] and Boyce [24], and subsequently described in the higher mammals by Beevor and Horsley [20] and Simpson [143A], consist of two sets, dorsal and ventral. The dorsal group leave the internal capsule opposite the upper third of the thalamus and run backwards to gain the outer side of the colliculus anterior, whereas the ventral group do not take origin from the pyramidal system until the crus is reached, when numerous fibres cross the corpus Luysii and extend to the posterior colliculus.

The present research has fully confirmed this grouping of the pallio-tectal system, and has further extended knowledge of the regions of the cortex whence the palliol-tectal fibres arise, so far as the temporal lobe and Rolandic regions are concerned.

The lesions of the temporal cortex given in Table I produced a characteristic degeneration of the pallio-tectal system, fibres being distributed to both colliculi as well as to the thalamus and pons, as described by Beevor and Horsley [20] (*see* figs. 18 *et seq.*, Cat 103).

TABLE I.—*Cortical Lesions.* (A) *Cat.*

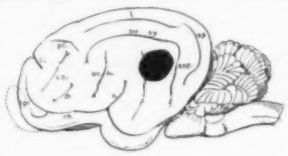
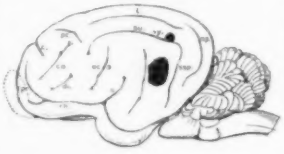
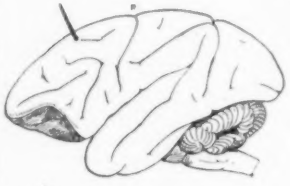
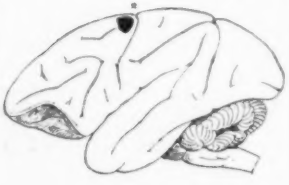
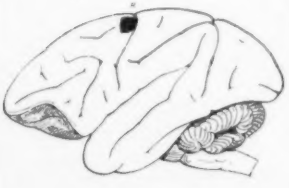
No.	Lesion	Diagram	Fibres to homo-lateral thalamus
Cat 99	Area 10 × 5 mm. on both sides of sulcus lateralis, anterior third of upper border of gyrus suprasylvius		Fibres in two groups to lateral nucleus separated by external geniculate; fibres dorsal to this mostly pallio-tectal, though some few break up in lateral nucleus of thalamus and pulvinar; those ventral to geniculate all end in lateral nucleus (ventral part)
Cat 135	Area 5 × 11 mm. Anterior half of gyrus anterolateralis and anterior end of gyrus suprasylvius medius		Fibres running through posterior part of thalamus; a few fine fibres also break up in nucleus lateralis (ventral portion)
Cat 139	Area 5 × 15 mm. Posterior part of gyrus post-cruciatus; gyrus suprasylvius medius and a corner of gyrus anterolateralis		A few fibres to nucleus lateralis ventral portion
Cat 127	Area 4 × 15 mm. Gyrus cruciatus posterior and anterior; gyrus suprasylvius (anterior extremity) coronalis (slightly)		A few very fine fibres in ventral portion of lateral nucleus
Cat 283	Area 8 × 12 mm. Post-crucial gyrus, anterior end of gyrus anterolateralis and gyrus suprasylvius medius		Fibres to ventral part of nucleus lateralis
Cat 131	Area 5 × 10 mm. Gyrus cruciatus anterior and posterior		Fine degeneration in nucleus lateralis ventralis

[1] These figures refer to the strength of the

(The number refers to the page in the Notes Ledger.)

Fibres to other regions	Symptoms	Remarks
Fibres pass into middle third of crus; from here behind corpus subthalamicum they pass up into anterior colliculus. A few fine fibres go anteriorly into subependymal tissue (fasciculus subcallosus), these traced forward to back of rostrum, and posteriorly only a short distance opposite about the middle of thalamus. Cord no degeneration	Slight loss of sense of position of contralateral fore-leg. No tactile and temperature sensory changes. Grips floor poorly with contralateral fore-leg	Electrical stimulation of sigmoid gyrus on operated side showed motor cortex normally active. Drooping and pricking of ear obtained from upper end of gyrus ectosylvius anterior. The latter weak. Current 2000'.
Pallio-tectal fibres in large numbers running across posterior part of thalamus to anterior colliculus; a very few degenerated fibres in pyramidal tract. Subependymal fibres are half the size of pyramidal fibres and take their origin to the inner side of the pyramidal fibres	Right fore-leg at times seems a little weak in gripping the floor. All else negative	
A few fibres to nucleus lateralis of contralateral thalamus. Fibres to nucleus of crus and tuber cinereum of both sides. Pallio-tectal fibres running through lateral nucleus and up in large numbers through nucleus ventralis and locus niger. These interlace with the fillet fibres. Many of large pyramidal fibres end in pons. Cord clear	Slight loss of sense of position of right fore-leg. All else negative. Grips floor poorly	
The degenerated fibres occupy the inner and middle third of the crus. Cross pyramidal tract degenerated in cord. Subependymal tissue shows no degeneration. A very few pallio-tectal fibres belonging to the cruro-tectal group	Loss of sense of position of right fore and hind leg. Loss to pain and temperature on right extremities. Grips floor poorly with right extremities	
A few inferior crural pallio-tectal fibres; pyramidal degeneration in cord	Loss of sense of position of right fore and hind leg; grips floor poorly with both these legs. Cold water not felt on both contralateral legs	
Extensive degeneration in pyramidal tract in cord	Slight loss of sense of position in right fore-leg; grips floor weakly with right fore-leg. Tactile sensation normal	Stimulation of the gyrus sigmoidalis gave strong contraction of right hind leg, but very weak ones of right fore-leg.

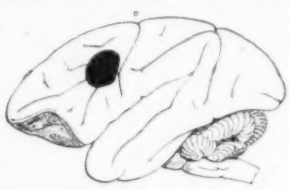
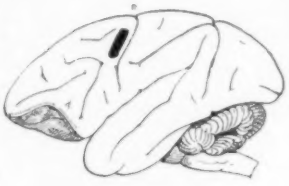
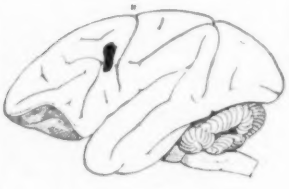
faradic current as indicated on the Kronecker coil.

No.	Lesion	Diagram	Fibres to homo-lateral thalamus
Cat 151	Area 10 × 10 mm. Gyrus ectosylvius posterior and medius		Fibres enter posterior part of nucleus lateralis above and a few below external geniculate ; some also go into pulvinar
Cat 181	Area 7 × 13 mm. Gyrus ectosylvius anterior and medius ; top of gyri Sylvii anterior and posterior		Fibres to ventral and *posterior* portion of nucleus lateralis
Cat 103	Area 5 × 5 mm. in gyrus ectosylvius posterior. A small injury in the gyrus suprasylvius medius		Fibres run through posterior part of lateral nucleus to anterior colliculus : some break up in lateral nucleus and in pulvinar region
			(B) *Monkey* (*Macacus*
Rh. 189	Leg area paracentral lobule, corona radiata (needle track)		Fibres break up in nucleus lateralis and zone grillagé
Rh. 317	Precentral gyrus leg area		Fibres (collaterals of second degree) to second, third, and fourth, fifths of lateral nucleus and to nucleus of lattice layer
Rh. 327	Precentral gyrus leg area		Fine collaterals to middle third of nucleus of lattice layer and lateral nucleus

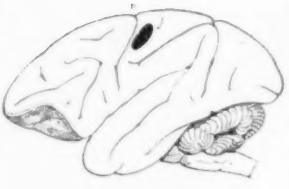
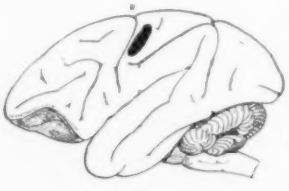
Fibres to other regions	Symptoms	Remarks
Pallio-tectal fibres to anterior colliculus and a few to posterior colliculus, Türck's bundle ending in pons as low as most anterior plane of fourth nucleus; fibres in stratum zonale pass into anterior colliculus; some fine fibres to internal geniculate. Cord no degeneration	Nil.	
Pallio-tectal fibres. Fibres in Türck's bundle	Nil.	
Fibres in capsule pass down to crus in outer third, including Türck's bundle. The internal portion except Türck's bundle run up into anterior colliculus and posterior colliculus. Türck's bundle ends in upper part of pons. Subependymal fibres run forward and back a very short distance. Cord no degeneration	Responds normally to all tests. No changes either motor or sensory	Gyrus sigmoidalis responds normally to faradic excitation.

Rhesus)—(1) *Gyrus Precentralis.*

Nil	Right arm and leg paretic	This case is also reported in Table II under Thalamic Lesions.
Dorsal third of corpus callosum to symmetrical point in opposite gyrus precentralis	(See later communication)	No pallio-tectal fibres.
Few fibres scattered through the vertical depth of the corpus callosum; few fibres scattered over crossed pyramidal area in cord	(See later communication)	Lesion very superficial; very few Betz cells affected.

No.	Lesion	Diagram	Fibres to homo-lateral thalamus
Rh. 185	Precentral gyrus; arm area almost completely destroyed		Fine fibres occupying middle third of lateral nucleus vertically and antero-posteriorly
Rh. 143	Precentral gyrus arm centre, and lower part of leg centre		Fine fibres run to ventral part of nucleus lateralis
Rh. 301	Precentral gyrus arm area		Fibres to second and third fifths of the nucleus of the lattice layer and the lateral nucleus

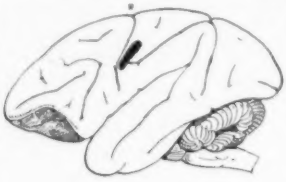
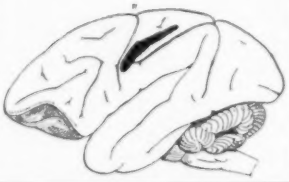
(2) *Gyrus*

Rh. 177	Postcentral gyrus opposite arm and leg centre; thrombus in corona radiata destroying presumably also precentral gyrus fibres		Fine fibres enter middle third of lateral nucleus and break up in its outer portion, occupying in area a narrow vertical slip
Rh. 165	Postcentral gyrus opposite arm and leg centres		Fine fibres to nucleus lateralis and to its ventral portion

Fibres to other regions	Symptoms	Remarks
Pyramidal degeneration in the cord	**Paresis of right arm.**	
Pyramidal fibres in cord	Two days after operation hemiplegic attitude of right arm and leg; knee-jerks equal; no extensor response of big toe. Eighteen days later: knee-jerk more active right than left; hemiplegic attitude of right arm; dorsal extension of toes of right foot; right big toe flexor; left toes all flexor; clumsy in jumping; sensation apparently normal (See later communication.)	Electrical stimulation gave with coil 500, movements of right arm, face and eyes; no movements of right leg; thumb movements obtained pre- and post-centrally.
Arcuate fibres pass to upper third of gyrus precentralis; generally distributed fibres in corpus callosum pass to opposite gyrus precentralis		

Postcentralis.

Fibres in pyramidal tract	Uncertain with right arm and leg when jumping; left arm used more readily than right; weak in right arm and leg; no alteration of sensation to be made out	Arm, leg and face centre excitable with faradic stimulus.
Nil	No motor or sensory changes to be made out; knee-jerks equal on both sides	Cortical stimulation showed no definite results, as monkey weak from diarrhœa; killed on eighteenth day.

No.	Lesion	Diagram	Fibres to homo-lateral thalamus
Rh. 300	Postcentral gyrus opposite arm centre		Fine fibres to ventral half of nucleus of lattice layer and ventral half of nucleus lateralis
Rh. 299	Postcentral gyrus opposite arm centre		Fine collaterals to nucleus of lattice layer and corresponding ventral half of the lateral nucleus

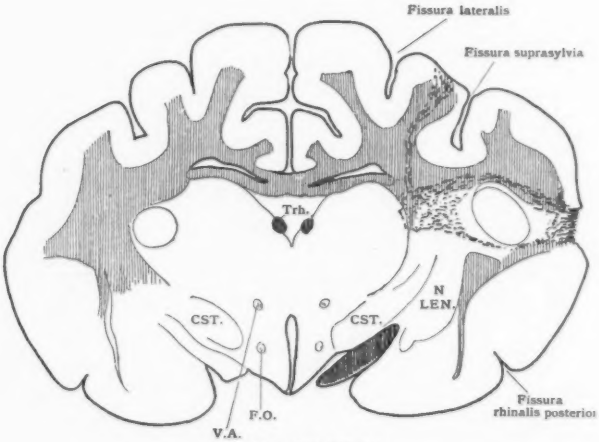


FIG. 18.—Cat 103 (I).

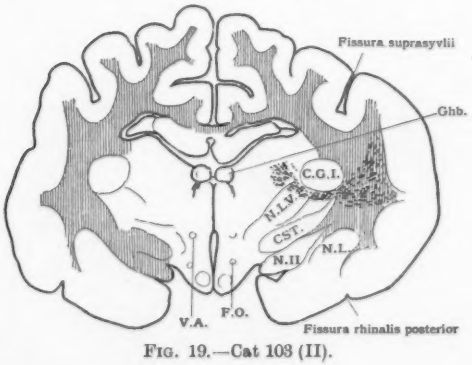


FIG. 19.—Cat 103 (II).

Fibres to other regions	Symptoms	Remarks
Medium fibres in corpus callosum crossing to corresponding contralateral cortex; very few fine collaterals to contralateral thalamus	(See later communication)	No pallio-tectal fibres; no pyramidal fibres traceable beyond pons.
Numerous fibres crossing corpus callosum in dorsal half to corresponding contralateral cortex; arcuates to upper part of postcentral gyrus from lesion; fine collaterals to corresponding contralateral thalamus nuclei	(See later communication)	No pallio-tectal fibres; pyramidal fibres of two classes—(1) the majority fine, (2) a few coarse. The former not traceable beyond the pons. The coarser extend in the cord as low as the lumbar region.

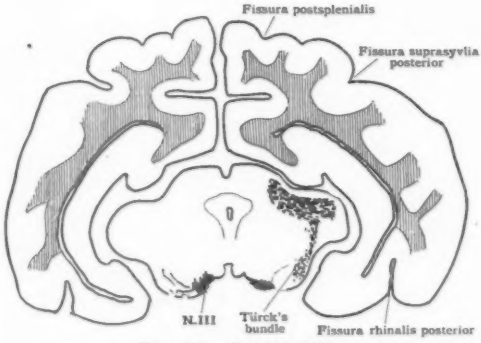


FIG. 20.—Cat 103 (III).

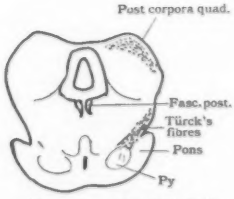


FIG. 21.—Cat 103 (IV).

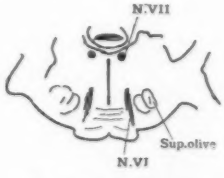


FIG. 22.—Cat 103 (V).

The lesions of the Rolandic region (excito-motor area), shown in Table I, are particularly interesting, as they appear to bring out a point which, if correct, would be of both morphological and physiological importance.

In the present research the limited lesions of the gyrus precentralis in the monkey (five operations), and of the sigmoid gyrus in the cat (one operation), correspond to the findings of Beevor and Horsley and

of Simpson respecting the post-crucial gyrus of the dog, in that they were not followed by any pallio-tectal degeneration. On the other hand, those lesions in the cat (see Table I) in which the gyrus coronalis was involved pallio-tectal fibres were found, and from a re-examination by Sir Victor Horsley of the series made by him in 1900-1902, by the undermining method, it is evident that in those experiments the corona radiata fibres of the gyrus coronalis were injured, and consequently that the pallio-tectal degeneration in the cat, observed by Beevor and Horsley, referred to lesions which involved the entire excito-motor cortex and were not limited to the sigmoid gyrus alone.

The interpretation to be put upon these facts is that while the cortical excito-motor area for the conjugate deviation of the head and eyes may be associated with the colliculi by pallio-tectal fibres, that for the limbs is not (*see* figs. 23 *et seq.*).

Further investigations on the monkey will decide this point.

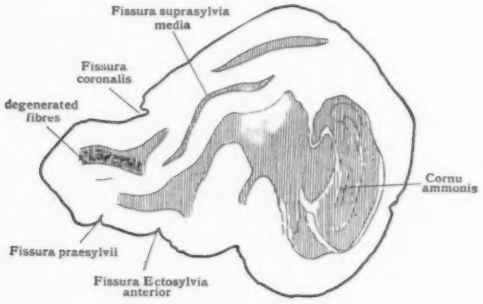


FIG. 23.—Cat 131 (I).

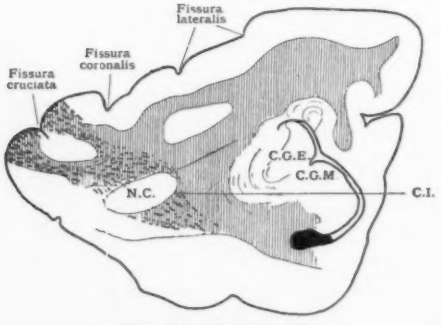


FIG. 24.—Cat 131 (II).

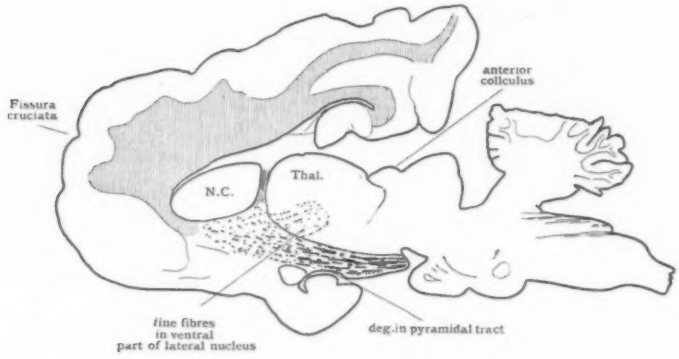


FIG. 25.

ELECTROLYTIC LESIONS IN THE THALAMUS.

Table II contains a description of the various thalamic lesions made in this research with the degenerations arising from each. Figs. 26 *et seq* are microphotographs of the lesions. In this way the need of lengthy descriptions of the lesions is met, and the matter made clearer. Each nucleus will be considered in detail, its relation to the rest of the thalamus and its connections with the rest of the nervous system defined, as far as is shown by these experiments. No tracts will be discussed other than those affected by the lesions.

Nucleus Anterior. (Figs. 26 and 27.)

This nucleus sends many fibres of very fine calibre along the ventral side of the caudate nucleus near its middle and anterior end. By the time the lateral side of the caudate is reached, practically all these fibres have entered the caudate. The few remaining fibres enter the caudate on the external, lateral or capsular side. No fibres pass to the cortex, and this fact further tends to substantiate Edinger's view that the nucleus caudatus belongs to the rhinencephalon. As the fibres from the anterior nucleus lose their medullary sheath as soon as they have entered the caudate, it is impossible to determine by this method how much of, or which part of, the caudate is specially connected with the anterior nucleus. The only fibres that pass back posteriorly are very fine ones, moderate in number, which lie first in the lamina interna and then break up in the outer part of the median nucleus.

I.—Lesions of Nucleus Anterior.

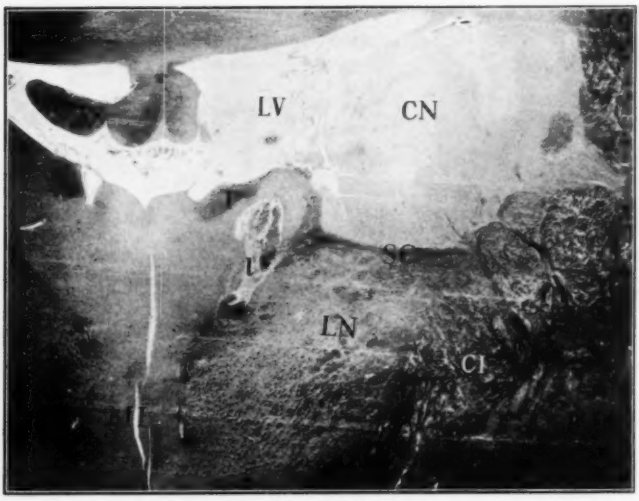


Fig. 26.—[Rh. 189.]

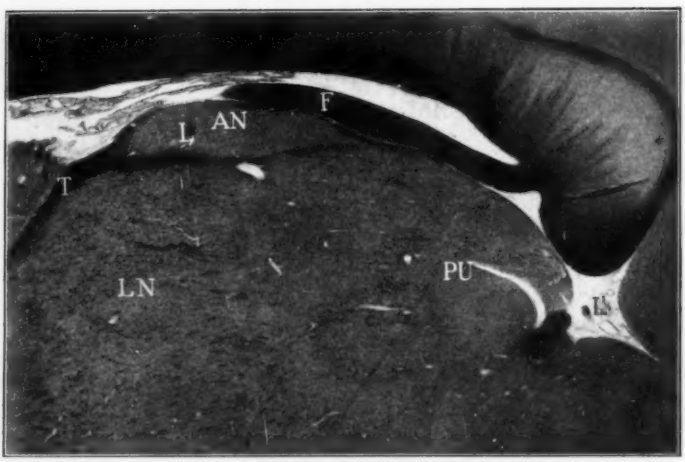


Fig. 27.—[Rh. 222.]

L by AN = The localized lesion in the nucleus anterior. A thrombosed vessel is marked L also just below the splenium.

No fibres were observed passing to any other region. The other thalamic nuclei were all clear. There were no degenerated fibres seen in the lower spinal axis, except in the pyramidal tract, in those cases in which the motor cortex was injured by the passage of the needle. It would seem, therefore, from the present research that the anterior nucleus is an intermediate station between the corpora mammillaria, from which it receives impulses coming through Vicq d'Azyr's bundle and the caudate nucleus.

As seen in fig. 26 S C, the fibres which, as above described, pass out to gain the caudate nucleus are gathered together in a felt-work or capsule separating the nucleus caudatus from the neighbouring more ventral nucleus lateralis. This is evidently a prolongation outwards of the stratum zonale, and, as it probably contains several systems of fibres, it should receive special attention and designation, such as *stratum subcaudatum*.

Nucleus Medius. (Figs. 28-30, inclusive.)

In Rhesus 169, 288, and Cat 95, lesions were made in the median nucleus. The lesions in the two monkeys were sufficiently far from the lamina interna to leave it absolutely intact. They constitute, therefore, a group by themselves, for which Cat 95 but furnished confirmatory evidence, since in that experiment the lesion involved slightly the internal superior third of the lateral nucleus.

The two pure lesions present a picture resembling in most respects that seen in the nucleus anterior, and lead to the inevitable conclusion that the latter must be classed in the same category with the median nucleus as part of the internal thalamic segment (Burdach).

Group I.—Lateral Fibres.

The outwardly directed fibres which become visible after lesions of the median nucleus pass out into the lamina interna at its superior portion, just below the nucleus anterior, and run obliquely across the superior part of the lateral nucleus, and end in the lower border of the caudate nucleus, where they break up into a large number of smaller fibres. In passing through the superior part of the lateral nucleus the fibres of the median are strictly confined to a triangular area bounded dorsally by the caudate nucleus, externally by the remainder of the dorsal third of the lateral nucleus, and internally by the anterior nucleus and lamina interna. As more fibres seem to enter this triangular area

II.—Lesions of Nucleus Medius.

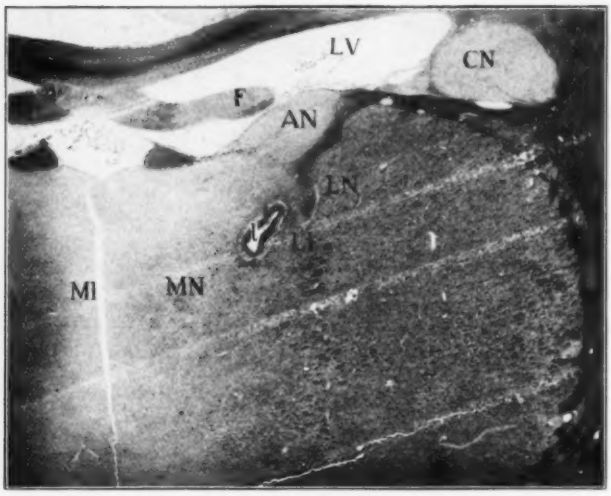


Fig. 28.—[Rb. 228.]

Lesion confined to outer segment of nucleus medius and sending fibres into lamina interna, &c.

Fig. 29.

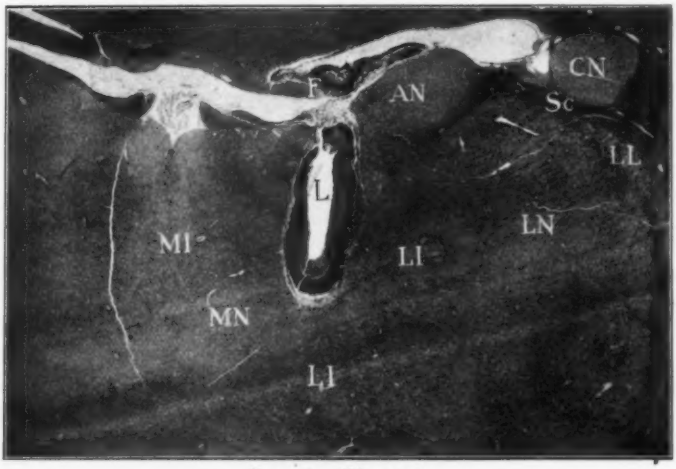


FIG. 30.—[Rh. 119.]

Lesion by vertical penetration. Numerous fibres passing out to stratum subcaudatum, S c. Note track of needle and electrolysis of fornix, F.

than pass beneath the nucleus caudatus, some of the fibres presumably end in the dorsal third of the lateral nucleus.

Group II.—Median Fibres.

The fibres proceeding inwards from the lesion are far fewer in number, they have an oblique inward course, are of fine calibre, and run but a short distance. Their direction is towards the lower and posterior part of the commissura mollis, but they cannot definitely be traced beyond about 2 mm. in the median nucleus. Their direction, however, suggests that their destination is the point mentioned above, which corresponds to the position of the nucleus reuniens first described by Edinger [45] in lower vertebrates, observed by Ziehen [161] in the marsupials, and which I [137] found to be constantly present in the mammalian thalamus.

In Rh. 169 a few fibres were traced to the centre median.

The foregoing were the only degenerations observed after lesion of the median nucleus.

Nucleus Lateralis. (Figs. 28-38 inclusive.)

If the nucleus lateralis be divided into thirds—dorsal, middle and ventral—it is easier to present what has so far been absolutely ascer-

tained by preceding authors concerning the anatomical relation of the nucleus.

The only points which may be properly termed proved are (1) the termination of the fillet, and (2) the ending of the superior peduncle of the cerebellum. Of these the former, first established by Monakow [109] and by Mott [110], and subsequently confirmed by all workers, has been further firmly established by Ramon y Cajal's description of the "nucleus" in the middle and ventral third of the nucleus lateralis, which he termed the "foco sensitivo" and its accessory nuclei.

The erroneous views of Tschermak [151], unfortunately accepted by many writers, viz., that the fillet fibres pass through the thalamus to the post-central region of the cerebral cortex, need not be now discussed; but the question of genuine transmission fibres running in this part of the thalamus becomes of great importance, as many—*e.g.*, the pallio-tectal series—pass through the lateral nucleus.

In three experiments in the present investigation the distribution of the fillet fibres as described, viz., in the ventral third and lower half of the middle third of the lateral nucleus, was well shown.

As regards the second point,[1] the yet unpublished results of a large series of experiments by Horsley and Clarke show that an important part of the distribution of fibres of the superior peduncles occurs in the upper part of the nucleus lateralis just above that of the fillet. This is in accord with the results of the stimulation experiments described below. At the same time it will be remembered that the rest of the distribution of the peduncle in the thalamus is wide—*i.e.*, in the ventral nucleus (Probst [123A]) and in the inner segment of Burdach of both thalami (van Gehuchten [62]).

The details of the cases of lesions strictly confined to the nucleus lateralis must now be considered, and particularly from the point of view of their demonstrating the existence and localization of the system of thalami-cortical fibres, which, though often described with confidence, had, as Roussy [135] shows, never been proved to exist by a pure lesion of the thalamus and consequent degeneration, until his experiment on a monkey.

The pure lesions of the nucleus lateralis obtained in the present research are seven in number, viz., six monkeys and one cat.

They are distributed as follows: Dorsal third, 228, 232, 240; middle third, 261, 270, 247 (cat); ventral third, 272 (dorsal border).

[1] This whole question, and especially the bilateral distribution of the peduncle, will shortly be discussed by Horsley and Clarke.

As before said, each lesion produces, as a rule, an external or laterally running group of degenerated fibres and an inwards directed or mesial group.

III.—Lesions of Nucleus Lateralis.

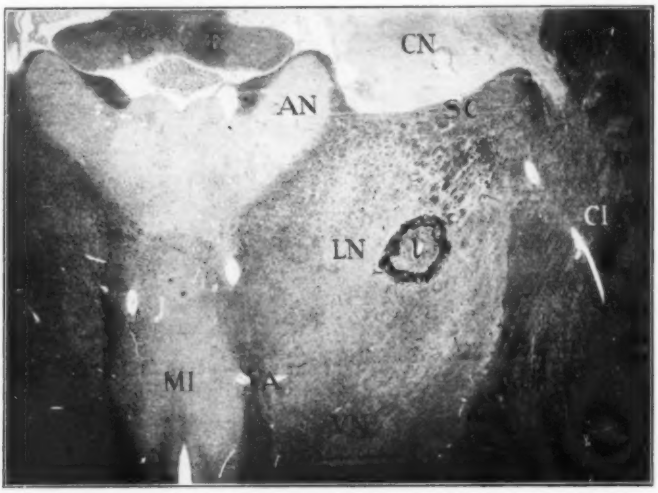


Fig. 31.

Lesion of upper third of nucleus lateralis, showing strong bundles of degenerated fibres running up and out into capsula interna and stratum subcaudatum.

Fig. 32.—[Rb. 261.]

Extremely localised circular lesion in nucleus lateralis.

Group I.—Lateral Fibres.

The first striking fact is, then, whereas from the median and anterior nuclei no fibres pass to the cortex directly, all the lesions of the nucleus lateralis cause degeneration of thalami-cortical fibres.

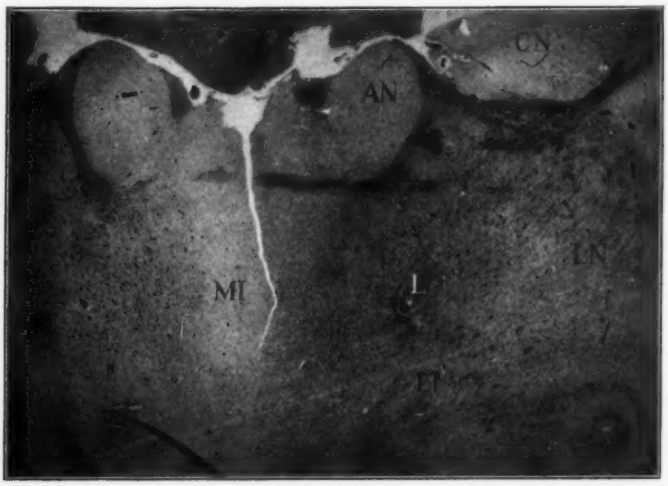


FIG. 33.—[Rh. 289.]

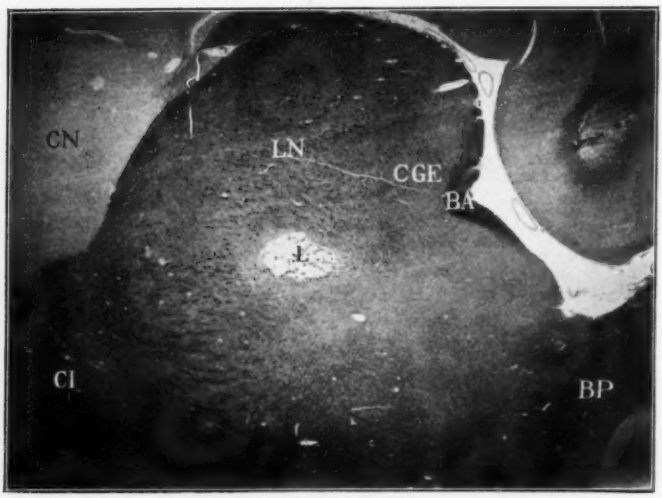


FIG. 34.—[Cat 247.]

The second, that the thalami-cortical fibres are revealed by this method to be arranged dorso-ventrally.

The third is, that the thalami-cortical fibres furnished to the two central gyri differ in number and size very materially.

FIG. 35.—[Rh. 232.]

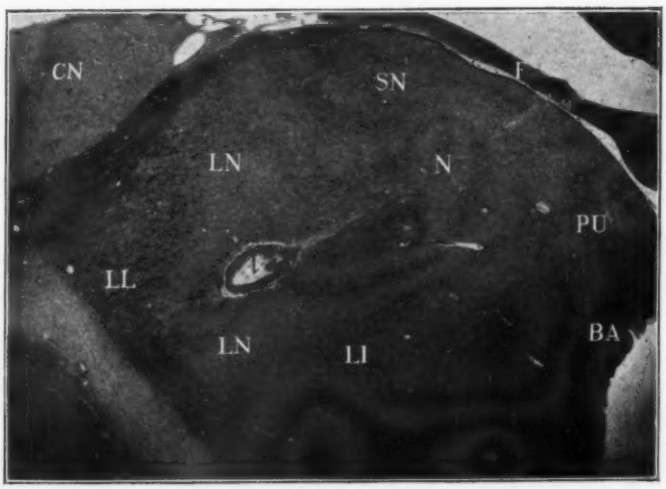


FIG. 36.—[Rh. 270.]

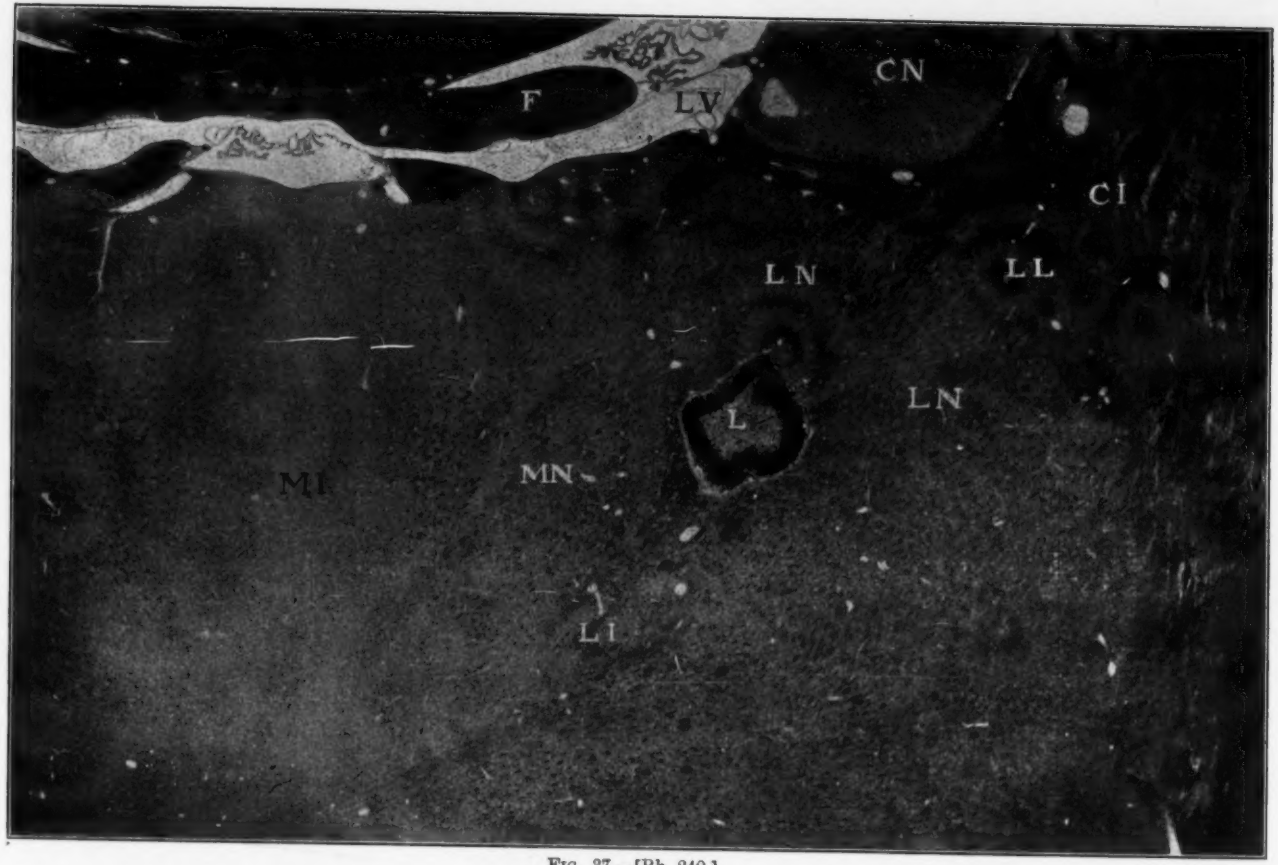


FIG. 37.—[Rh. 240.]

Lesion of inner border of nucleus lateralis, showing clearly both the medial group of inwards-running fibres and the outer group passing to the capsula interna.

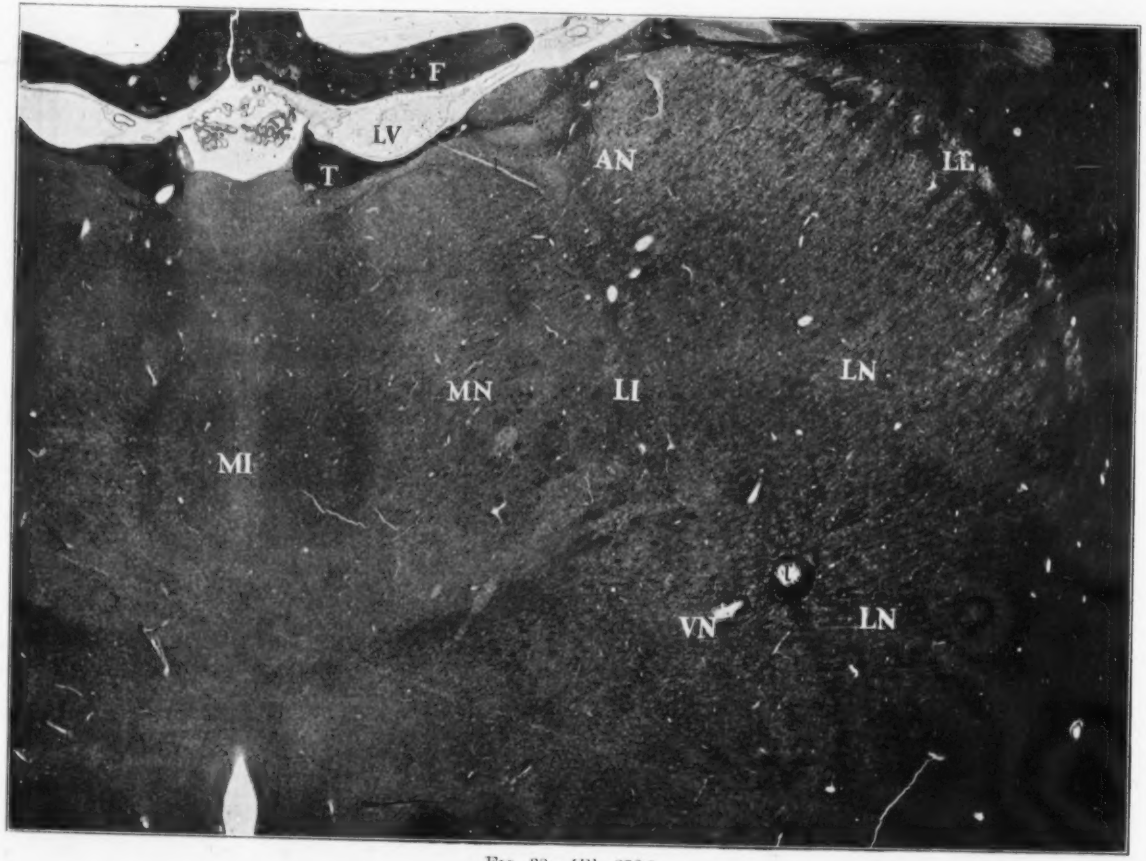


FIG. 38.—[Rh. 272.]

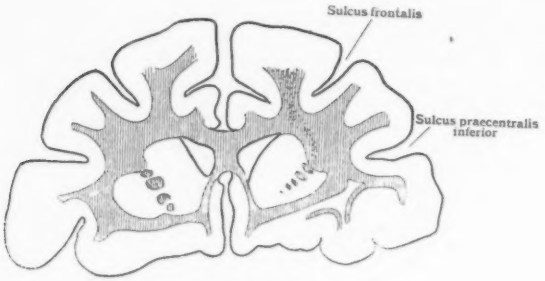


FIG. 39.—Rhesus 261 (I).

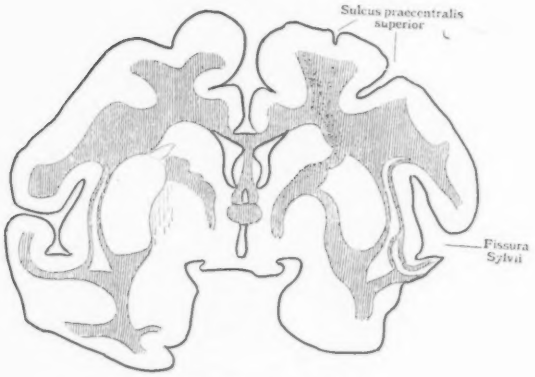


FIG. 40.—Rhesus 261 (II).

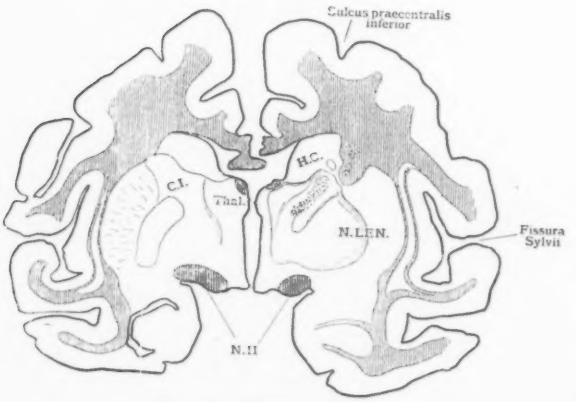


FIG. 41.—Rhesus 261 (III).

The first point confirms the fundamental conception of Burdach before referred to, and will perhaps lead to wider generalizations on the comparative neurology of the thalamic nuclei. From the most anterior portion of the nucleus lateralis fibres proceed, as seen in figs. 39, 40, &c., from Rh. 261, to the gyrus frontalis superior. The

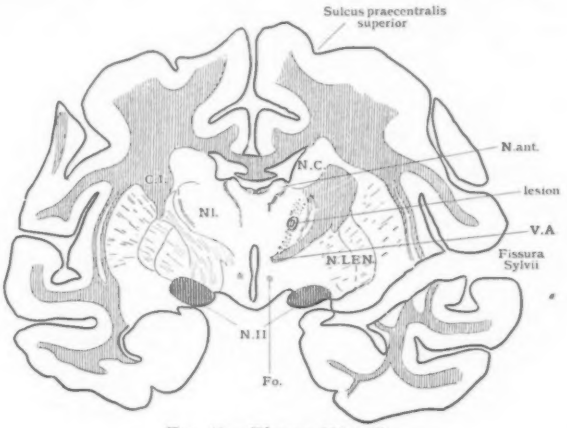


FIG. 42.—Rhesus 261 (IV).

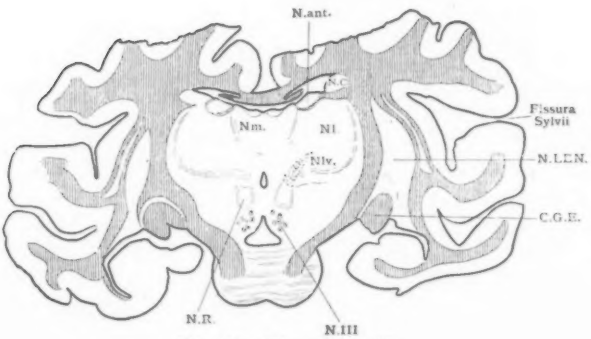


FIG. 43.—Rhesus 261 (V).

second point is one of great practical import, and must receive further attention. In the first place the thalami-cortical fibres derived from the lesions of the ventral region of the lateral nucleus are distributed only [1] to the so-called motor area and the post-central gyrus.

[1] It will be noted that this statement is conditioned by reference to the exact lesions photographed. It is, of course, left open whether the neighbouring parts of the nucleus lateralis send fibres to regions of the cortex other than those specified.

Furthermore, from the dorsal part of the nucleus lateralis thalami-cortical fibres pass in numbers to the lower limb area of the cortex, from the middle part to all three areas—lower limb, upper limb, face; while from the lowest lesion of all the degeneration can be traced into the operculum and facial centre only.

This dorso-ventral topographical order of representation is what might be expected to exist, but the strikingly sharp delimitation of the face from the limb areas as receptors of thalami-cortical fibres could not have been justly surmised.

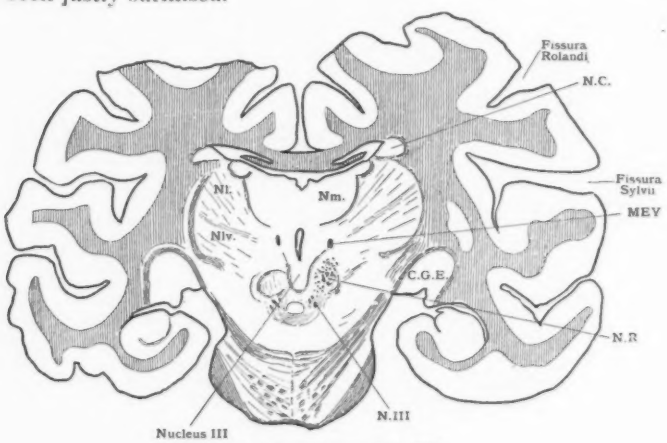


FIG. 44.—Rhesus 261 (VI).

Reference to figs. 45-48 will show better than description how extremely sharply defined is the supply of thalami-cortical fibres to

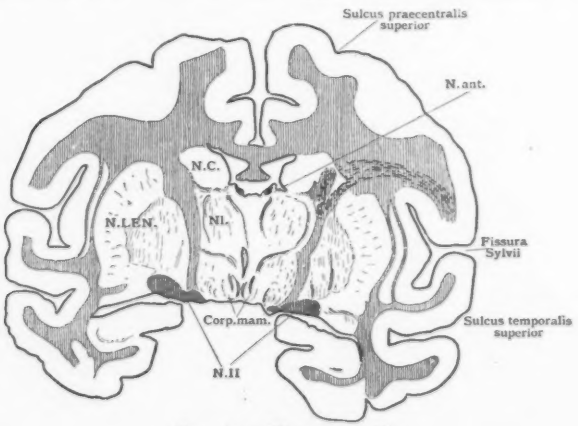


FIG. 45.—Rhesus 272 (I).

the face area, and how this affords a contrast to the associated supply of the two limb areas.

As regards the recent work by Brodmann and Campbell [29] on the distribution of the large Betz cells of the so-called motor region, it will be seen that in part this distinction between the two groups of thalami-cortical fibres follows the grouping of the large pyramidal cells, but more

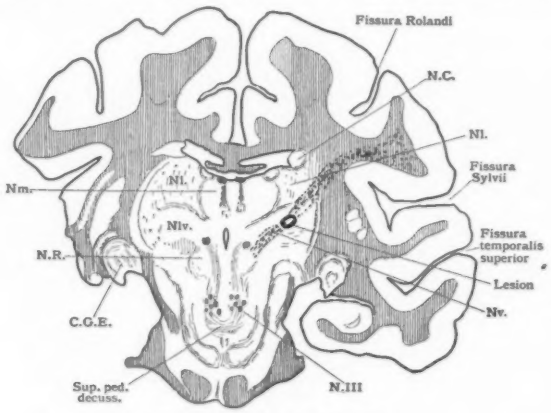


FIG. 46.—Rhesus 272 (II).

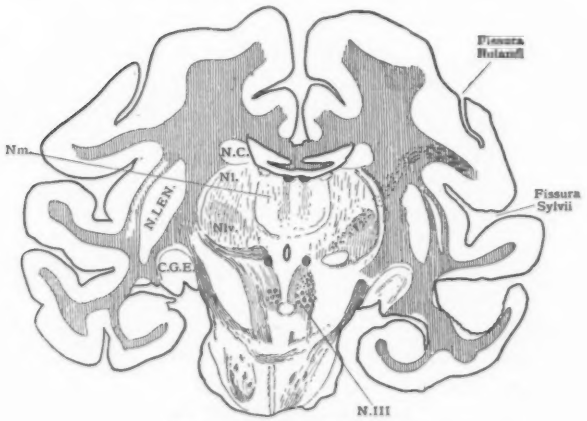


FIG. 47.—Rhesus 272 (III).

cannot be said on this point as yet. It, however, leads naturally to the next question, the third named above—*i.e.*, the distinction in number and size of the thalami-cortical fibres supplying the pre-central and post-central gyri respectively. From sagittal section-series it was at once

evident that far more thalami-cortical fibres proceeded to the pre-central than to the post-central gyrus. This discovery was contrary to preconceived opinions, and therefore was investigated with special care. It then became clear that, besides the question of number of fibres, their relative diameter must be taken into account; and it was found that, whereas the pre-central received a large number of fibres, a few of which were large, very many medium, and some fine, the post-central received fine fibres, with a very few medium ones.

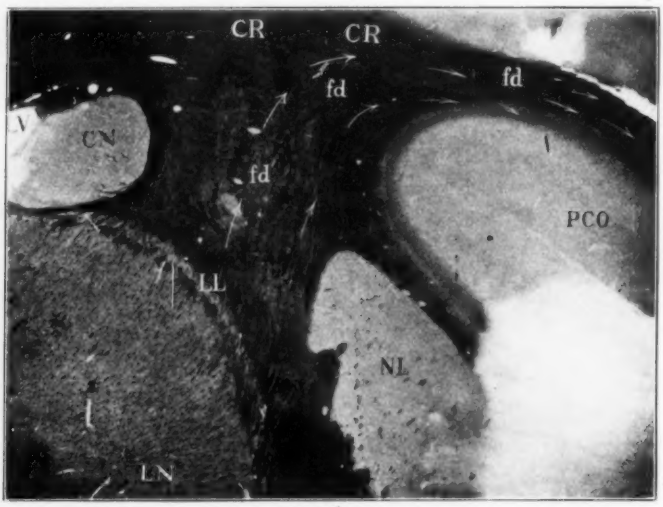


FIG. 48.

Clearly there is a definite morphological difference in the supply of fibres to the two gyri from the optic thalamus, and the net result is that a larger number and larger-sized fibres pass to the pre-central gyrus (gyrus frontalis ascendens).

Group II.—Mesial Fibres.

In three cases[1] it was found that from the inner side of the lesion medium-sized and fine fibres passed to the "centre median" and the nucleus arcuatus (*see* figs. 35-37). This is especially important, as the lesions furnishing these connection paths are all situated in the dorsal third of the nucleus lateralis. A certain degree of fine degenerated fibres and collaterals (?) can be seen extending all around the lesions for about one-fourth of the diameter of the nucleus.

[1] Rh. 228, 232, 240.

Lamina Interna.

In two cases—Rh. 111 and Rh. 289—the lesion was situated in the lamina interna, and caused consequently a limited destruction of the inner margin of the lateral nucleus.

IV.—Lesions of Lamina Interna and Adjacent Nucleus Lateralis.

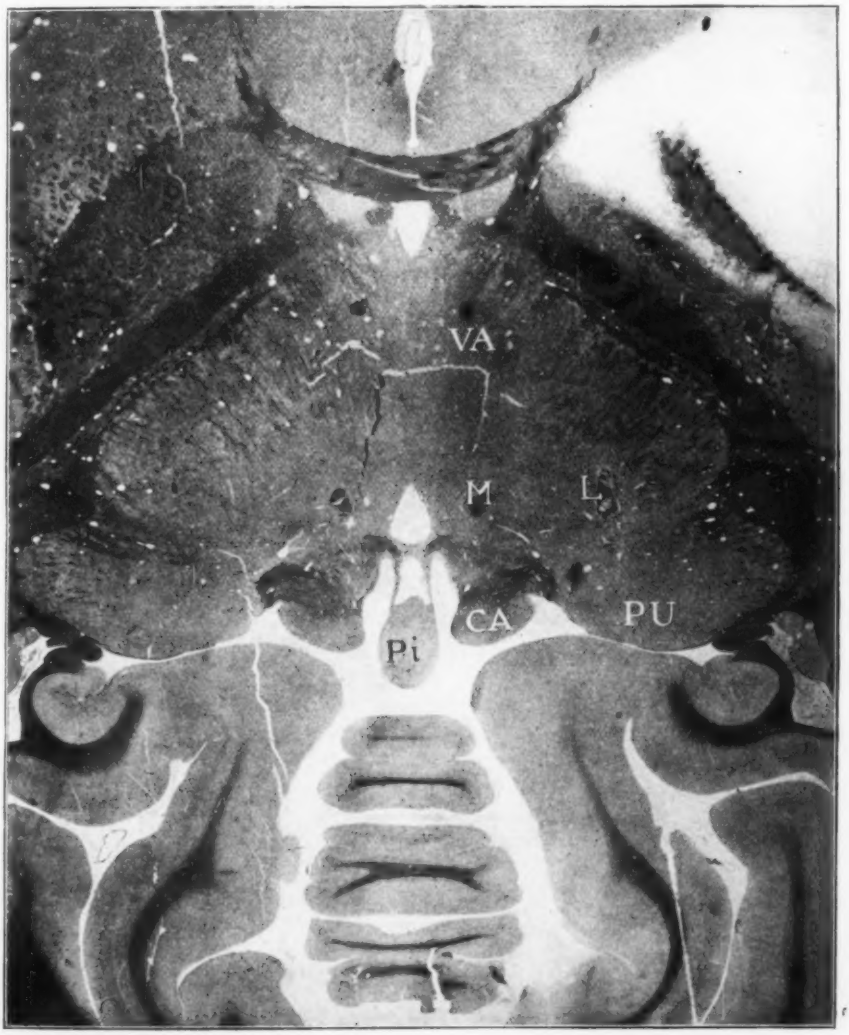


Fig. 49.—[Rh. 267.]

FIG. 50.—[Rh. 111.]

The resultant degenerations were the same as those of a primary and restricted lesion of the lateral nucleus.

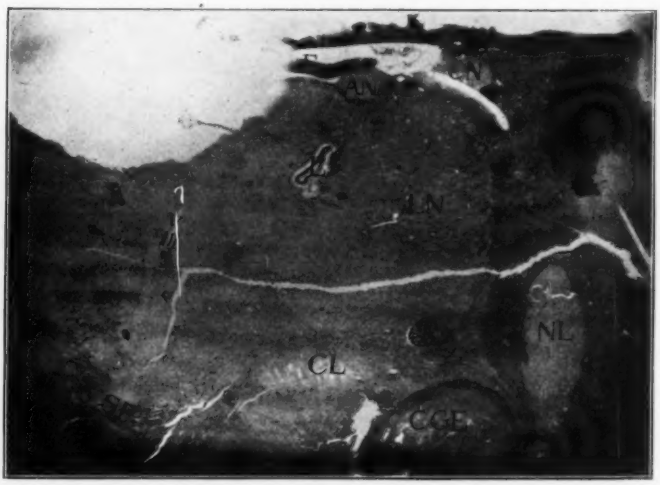


FIG. 51.—[Rh. 111.]

FIG. 52.—[Rh. 255.]

Lesion of upper angle of nucleus lateralis dividing also the tænia thalami.

V.—LESIONS OF CAPSULA INTERNA AND ANTERIOR MARGIN OF NUCLEUS LATERALIS.

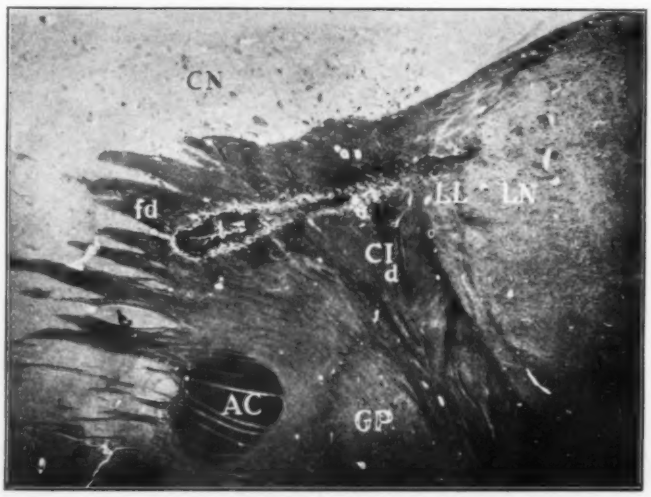


FIG. 53.—[Rh. 258.]

Lesion of genu and pars anterior of capsula interna.

fd = thalami-subcaudate fibres degenerated.
d = pyramidal (descending) fibres degenerated.

FIG. 54.—[Rh. 236.]

Note the considerable mass of thalami-cortical fibre degeneration.

Centre Median and Nucleus Arcuatus.

These two nuclei have been grouped together as they are closely connected with one another, and seem to receive similar fibre supplies. This idea has been prevalent for some years, though no positive proof in support thereof has hitherto been furnished.

Lesions in this region were successfully made in five animals. In Rh. 216 and Rh. 218 the lesions were confined almost exclusively to the nucleus arcuatus; in Rh. 275 the centre median alone was injured; in 267 the border between the centre median and nucleus lateralis was injured, but so slightly that none of the degenerations characteristic of a lateral nucleus lesion—as described in the preceding pages—were observed. In Rh. 87 both the centre median and nucleus arcuatus

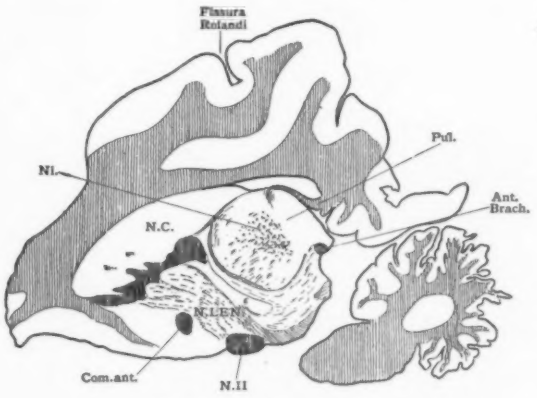


FIG. 55.—Rhesus 275 (I).

were destroyed, as well as a considerable portion of the nucleus ventralis.

Three principal facts are observed in these cases:—

First.—The complete absence of thalami-cortical fibres. Not only were no fibres ever seen going to the cortex, but all fibres from centre median and arcuate lesions stopped in the inner half of the lateral nucleus—*i.e.*, before they reached the internal capsule (*see* figs. 55, 56).

Second.—That all the fibres go to the nuclei immediately adjacent, and that these fibres all run a short course, yet are of medium calibre. When the nucleus arcuatus was involved, as in Rh. 216, 218, and 87, fibres passed from it to all the thalamic nuclei, with the exception of the

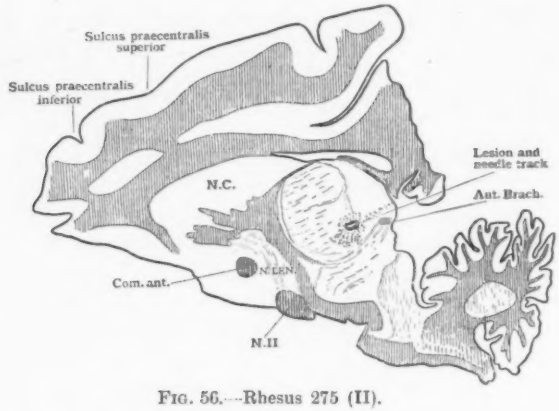


FIG. 56.—Rhesus 275 (II).

VI.—LESIONS OF CENTRE MEDIAN AND IMMEDIATELY ADJACENT REGIONS.

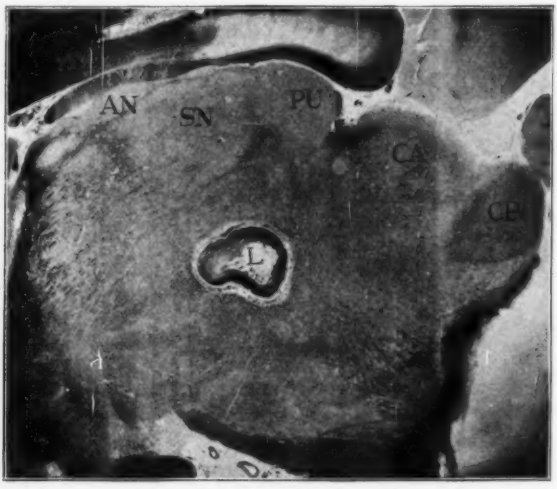


FIG. 57.

nucleus anterior. When the centre median was alone involved, as in Rh. 275 and Rh. 267, no fibres entered either the median or anterior nuclei, but many passed to all the other thalamic nuclei.

FIG. 58.—[Rh. 273.]

Third.—There were no descending fibres to the mesencephalon.

These facts clearly show that the centre median and nucleus arcuatus are association centres and connect the various nuclei with one

FIG. 59.—[Rh. 273.]

FIG. 60.

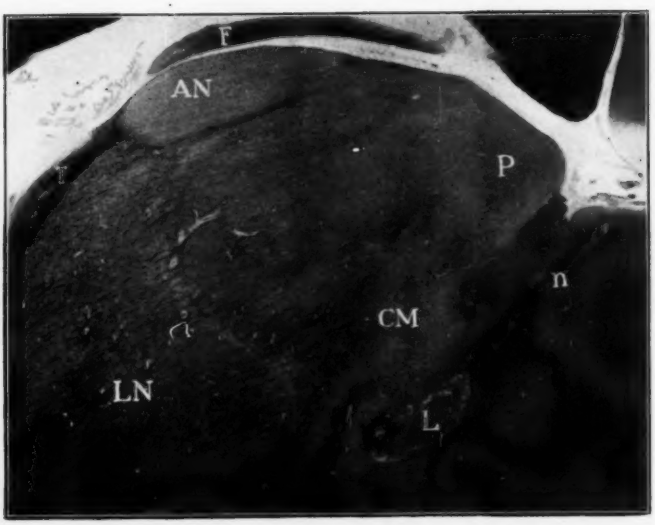


FIG. 61.

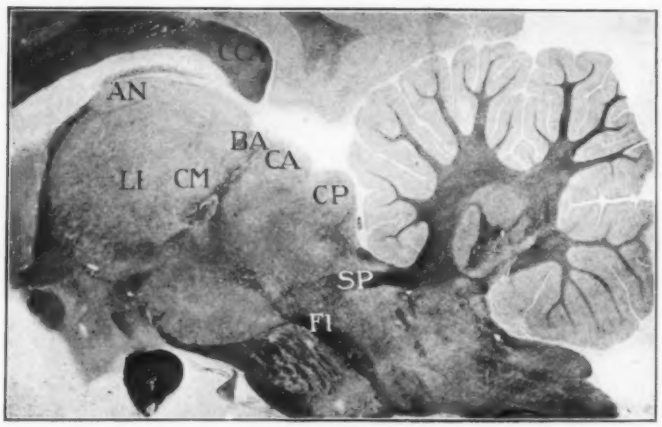


FIG. 62.—[Rh. 218.]

another, though they seem to be much more intimately associated with the lateral part of the thalamus than with the median portion. The advisability, therefore, of keeping the original name suggested by Luys seems apparent.

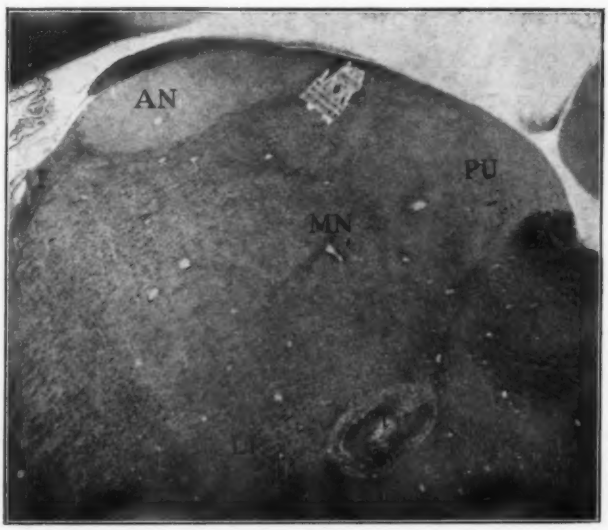


FIG. 63.

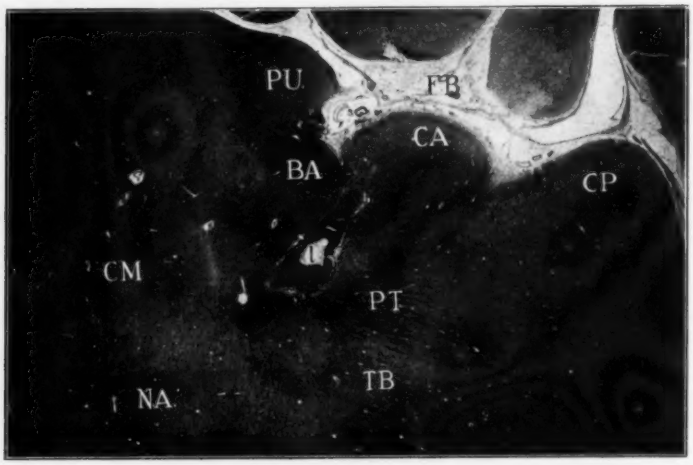


FIG. 64.—[Rb. 273.]

In Rh. 87 a further important point developed, which is well shown on fig. 66. The lesion, as described in Table II, injured the nucleus ventralis. From this region the posterior longitudinal bundle is seen to degenerate downwards, and sends collateral fibres to the following cranial nerves: V, VI, VIII, X.

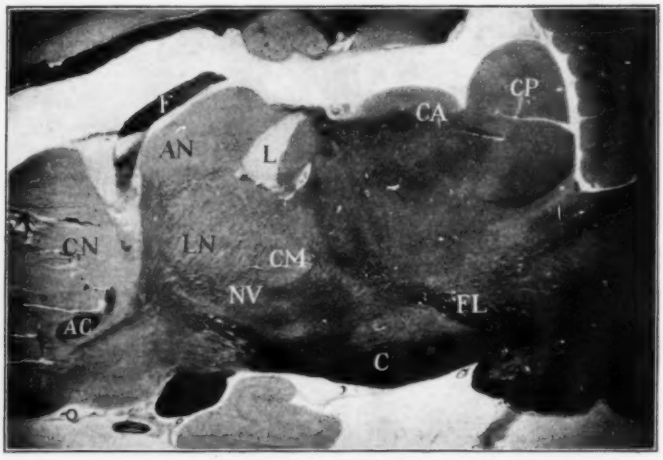


FIG. 65.—[Cat 95.]

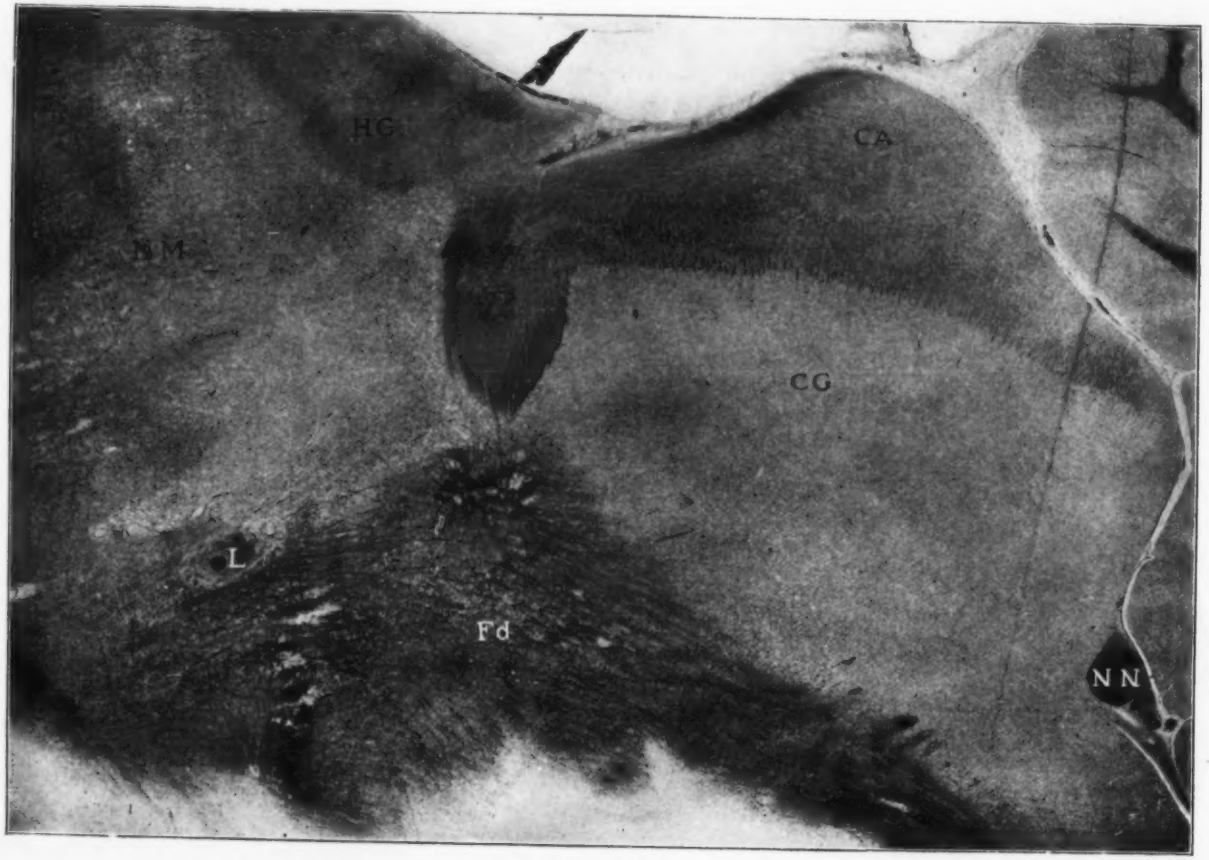


Fig. 66.- [Rh. 87.]

Held [70] and van Gehuchten [62] regarded the posterior longitudinal bundle as a descending tract, while Kölliker [83] and Cajal [28] believed it was an ascending one. The first two observers differed as to the origin of the tract. Held thought it came from the anterior colliculus, while van Gehuchten found it arose from the grey substance just above the third nucleus, which he calls the superior nucleus of the posterior longitudinal bundle. As a matter of fact the bundle contains both ascending and descending fibres, and in the present case evidently the latter portion arises higher than those observers thought —namely, in the ventral nucleus of the thalamus. This is the only instance found in these experiments of any fibres from the thalamic region going into the spinal cord.

The injury in Rh. 87 to Meynert's bundle caused its degeneration down to the interpeduncular ganglion.

Pulvinar.

No lesions were made in the pulvinar alone, since to obtain control observations on this region the needle should be introduced from the front, and, as the technique of this procedure would have involved special alterations of the apparatus, this part of the examination of the thalamus was left to a future research.

Hypothalamus.

In the course of this work several lesions were made in regions adjacent to the thalamus, and as the resultant degenerations throw more light on the relations of the thalamus to the surrounding centres they will be now described.

These cases were Rh. 203, 207, 251, and 211. The first three have many points in common.

In all these the median fillet was injured, either as it passed around the outer side of the red nucleus, or somewhat more dorsally, or again anteriorly, where it begins to spread out into the ventral portion of the lateral nucleus. As a result of these lesions the final distribution of the fillet is well seen, and again proves beyond all question that the view of Tschermak [151], that the fillet fibres end in the cortex, is not correct.

In Rh. 207, where there was a slight injury to the ventral nucleus, a few fibres could be traced towards the opercular region, where they branch off from the internal capsule above the island of Reil. As

they were not traced to the cortex the observation is incomplete, but they tend to confirm the findings in Rh. 272. Except for the fillet fibres, no other fibres pass to the thalamus from Forel's field, which was involved in each of these lesions, and in Rh. 207 the few fibres entering the arcuate and centre median arise from the point of injury of the ventral nucleus.

The lesions may now be considered in detail under the head of (*a*) Forel's field; (*b*) Nucleus ruber.

(*a*) *Forel's Field.*

Of the three cases of lesions in this region, Rh. 203 and 207 exhibited the focus as situated in the junction of the outer and middle thirds of the more dorsal part of the field, while in Rh. 251 the lesion

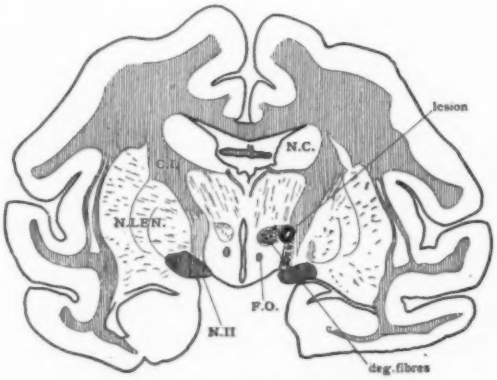


FIG. 67.—Rhesus 251 (I).

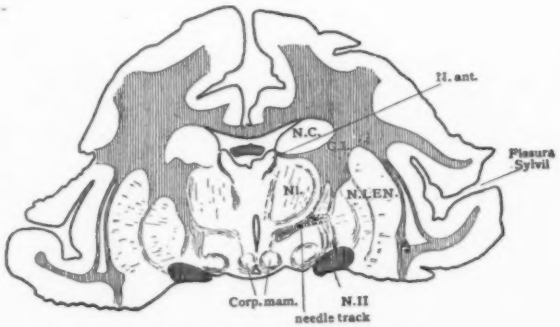


FIG. 68.—Rhesus 251 (II).

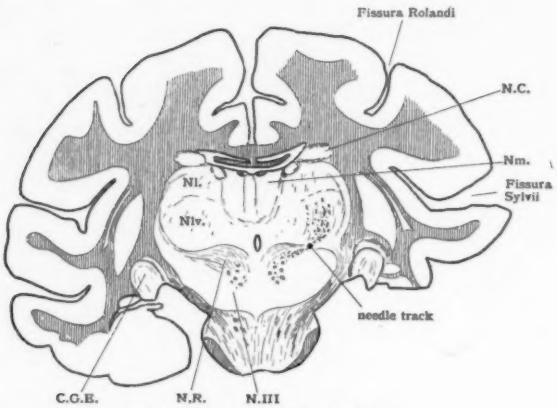


FIG. 69.—Rhesus 251 (III).

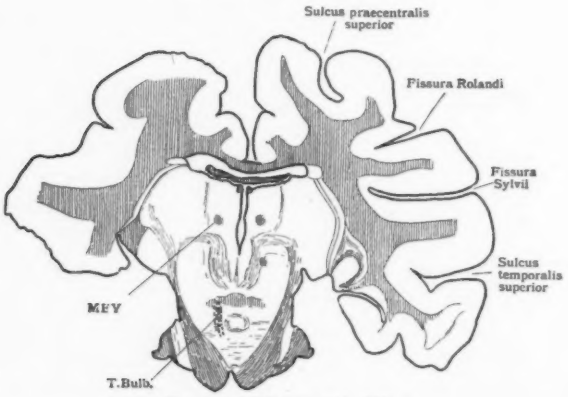


FIG. 70.—Rhesus 251 (IV).

was situated in the middle of the field, slightly ventrally of an equatorial line. In this case anteriorly the lesion involved the base of the internal capsule. Apart from the concomitant consequences above described of injury to the neighbouring fillet or ventral nucleus, there were to be seen two groups of degenerated fibres proceeding horizontally from the lesion and forming a lateral and a mesial group (*see* figs. 67-70).

Group I.—Lateral Fibres.

These were coarse and medium-sized fibres which passed horizontally outwards in a well-marked bundle interlacing at right angles with the

basal third of the internal capsule, and entering the globus pallidus, in which they broke up. A few reached the middle zone of the nucleus lenticularis, but none passed into the putamen.

Group II.—Mesial Fibres.

The mesial degeneration consisted of (1) a very interesting mass of fine and medium-sized nerve fibres forming the "inferior peduncle of the thalamus" (Dejerine) (*see* figs. 67, and 71 and 72 FOR), but which is in essence the frontal section of the ansa lenticularis; (2) coarse and medium fibres to the nucleus ruber, &c.

(1) Of these the fine fibres in the degenerated ansa group pass backwards (none forwards); some give fine collaterals to the side of the tuber cinereum (none internal to the fornix), but the main body continue spreading over the whole of the medial part of the field of Forel and sending numerous fine collaterals or ending in the ventral nucleus. Finally, the remainder cease in the anterior capsule of the red nucleus.

(2) The fibres which pass down to the nucleus ruber break up in its inferior capsule, and in a few instances cross the commissure of Forel and gain the capsule of the opposite nucleus ruber.

(b) Nucleus Ruber.

In one experiment [Rh. 211], the lesion was placed in the ventral half of the dorsal (anterior) nucleus of the nucleus ruber (*see* fig. 75).

The fibres observed to degenerate therefrom are divisible into a lateral and a mesial or ventral group, as in the case of the other nuclei.

(1) *Lateral Fibres.*—A small number of medium-sized fibres passed outwards and upwards into the lateral nucleus and into the centre median. According to Horsley and Clarke these are fibres of the superior cerebellar peduncle, *i.e.*, fibres in transit, but whether any also arise within the injured nucleus cannot be decided.

(2) *Mesial Fibres.*—These are traceable downwards and inwards, crossing in Forel's commissure and divisible into two groups, as described in Table II, viz., rubro-spinal and rubro-bulbar. The former, being slightly marked by but a few fibres, require no discussion, but it is important to point out that the rubro-bulbar tract observed in this case is naturally not the same as that described by Münzer and Wiener [112] as tractus-tecto-bulbaris, but lies rather further from the median plane.

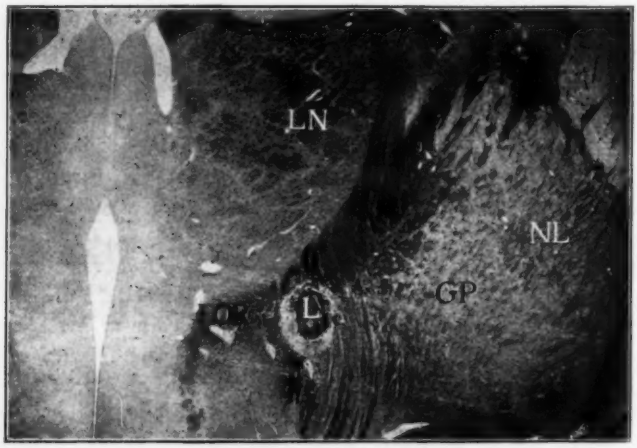


FIG. 71.—[Rh. 251.]

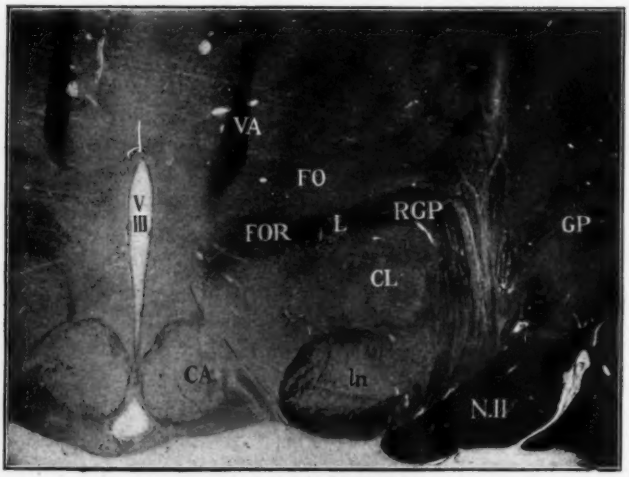


FIG. 72.—[Rh. 251.]

Section further caudal to preceding, showing the globus pallidus fibres RGP crossing the lower part of the genu of the capsula interna.

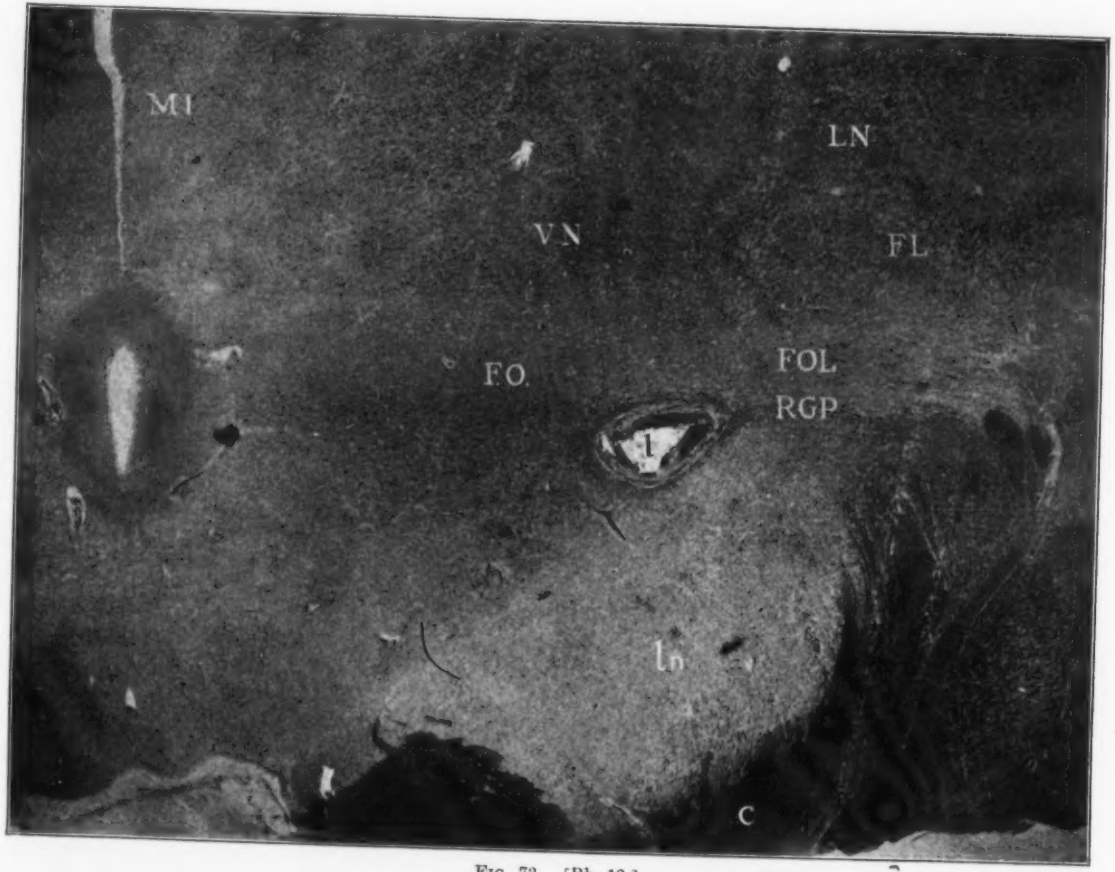


FIG. 73.—[Rh. 13.]

FIG. 74.—[Rh. 207.]

FIG. 75.—[Rh. 211.]

TABLE II.—*Thalamic Lesion.* (*Rh.* = *Macacus rhesus.*)

Lesions of

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 189	Nucleus anterior	Fine fibres degenerated in anterior limb of internal capsule close to caudate ending indeterminate	Lesion	Fine fibres break up here in outer border running back from lesion	Nil	Nil	Nil ... ...
Rh. 222	Nucleus anterior and Vicq d'Azyr's bundle just below the nucleus	Nil	Lesion; a few fibres from injury to Vicq d'Azyr's bundle seen entering nucleus anterior	Indeterminate	Nil	Nil	Nil ... ...
Cat 255	In anterior part of fornix; Vicq d'Azyr's bundle just before it enters nucleus anterior, needle track passes through nucleus lateralis	Fibres to cingulum along its entire length; a few coarse fibres to gyrus lateralis, suprasylvian and anterior ectosylvian from needle track, finer fibres through the caudate chiefly at its anterior and outer pole, to gyrus cruciatus posterior	Fine fibres break up here; they come from Vicq d'Azyr's bundle	Nil	Lesion ...	Nil	Nil ... ...

Lesions of

Rh. 111	Involves outer border of median nucleus, lamina interna, and internal portion of lateral nucleus	Leg and arm area of precentral gyrus and about to junction of middle and lower thirds of precentral gyrus, part of face centre, most fibres to leg centre	Needle track passes through capsule of nucleus; a few fibres from lesion posteriorly ascend to lower border of anterior nucleus and appear to end there	Lesion; fine fibres break up in posterior part of nucleus	Lesion ...	Nil	Nil .. ..

Summary of Degenerations Observed.

Nucleus Anterior.

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere.	Remarks.
Nil	Nil	Nil	Nil	Pyramidal degeneration due to needle track	To caudate ...	Needle introduced vertically.
Nil	Nil	Nil	Nil	Nil	All end in caudate	This lesion was due to an embolus which lodged in the nucleus anterior and caused a small necrosis. Through a miscalculation the electrolysis occurred in the ventricle in front of anterior colliculus, and from here the vessel in which embolus occurred can be traced. Needle introduced horizontally.
Nil	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.

Nucleus Medius.

Nil	Nil	Nil	Nil	Pyramidal fibres degenerated due to passage of needle	Some fibres from nucleus lateralis go to outer part of ganglion habenulæ	Needle introduced horizontally.

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 169	Median nucleus ...	Nil	Nil	Lesion in outer half, but separated from lamina interna by a considerable portion of uninjured nucleus	Fibres pass through dorsal part just below nucleus anterior	Nil	Nil ... ..
Cat 95	Median nucleus ventral third of pulvinar posterior limit is Meynert's bundle, which is involved	Pre- and post-crucial gyri and olfactory tubercle	Nil	Lesion ...	Internal surface just touched	Nil	Nil ... ...
Rh. 288	Median nucleus in its upper and outer portion, quite free of the lamina interna	Nil	Nil	Lesion ...	The fibres coming out of the nucleus medius pass obliquely across the superior portion (dorsal fourth); some may end here	Nil	Nil ... ...

Lesions of Nucleus

Rh. 228	Ventral border of dorsal third of nucleus lateralis and most anterior portion of pulvinar	Pre- and post-central gyri arm and leg area; fewer fibres to face region. More fibres to gyrus precentralis than postcentralis	Nil	Medium fine degeneration; source either nucleus lateralis or lamina interna	A few fibres to nucleus of opposite side	Nil	Nil ... ..
Rh. 232	Between dorsal and middle third of nucleus lateralis	Large number of fibres to precentral gyrus leg and arm area; extremely few and finer calibre fibres to face area and postcentral gyrus	Nil	Nil	Lesion ...	Nil	Nil .. ...
Rh. 240	Junction of dorsal and middle third of nucleus lateralis	Many fibres to leg and arm area of precentral gyrus; some fibres to postcentral gyrus; fine fibres to superior and middle frontal gyri as far forward as the plane of anterior end of caudate nucleus	Nil	Nil	Lesion; fine fibres seen all through nucleus in neighbourhood of lesion	Nil	Nil ... ...

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere	Remarks
Fibres cross lamina interna and break up here	Nil	Nil	Nil	Pyramidal degeneration due to passage of needle	Fibres running across dorsal part of lateral nucleus end in caudate nucleus; fibres degenerated due to injury of tænia thalami run back and end in outer half of ganglion habenulæ	As needle introduced vertically cortical fibres obscure the picture and make it impossible to express an opinion as to thalamicortical fibres, though fibres from median all seem to have ended in caudate.
Nil	Partial lesion	Nil	Nil	Nil	Meynert's bundle degenerated to interpeduncular ganglion	Needle introduced vertically.
Nil	Nil	Nil	Nil	Nil	Fibres enter capsule on lower border of caudate and break up there	Needle introduced vertically.

Lateralis (A) *Dorsal Third.*

Medium-sized fibres break up herein	Nil	Nil	Nil	Nil	To external geniculate of opposite side (needle track passed through splenium)	Needle introduced horizontally.
Some fine fibres break up herein	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Some fine fibres break up herein	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 289	Needle track and posterior part of lesion in lamina interna; anterior part of lesion in dorsal and internal third of nucleus lateralis. It occupies an area one fourth the cross diameter of lateral nucleus	Fibres to dorsal half of precentral gyrus as far forward as the superior precentral sulcus and to the angle in front of the inferior precentral, *i.e.*, around the posterior end of the inferior frontal sulcus	Nil	A few fibres run backwards and downwards and break up in outer part of median nucleus	Lesion as described	Nil	Nil ... ...
							Lesions of Nucleus
Rh. 261	Middle third and anterior part of nucleus lateralis	Fibres to precentral gyrus; arm and leg area; none to operculum, very fine fibres in superior frontal gyrus to plane of anterior end of caudate.	Nil	Nil	Lesion ...	Nil ...	Nil ...
Rh. 270	Ventral border of middle third of nucleus lateralis	Fibres to pre- and post-central gyri, many fibres to leg and arm area, a few to face centre, none to lowest part of face centre; a very few post-centrally	Nil	Nil	Lesion ...	Nil ...	Nil ...
Cat 247	Junction of middle and lower third of nucleus lateralis	Pre- and post-crucial gyri; sigmoid and anterior part of lateralis	Nil	Nil	Nil ...	Lesion ...	Nil ..
							Lesions of Nucleus
Rh. 272	Dorsal border of ventral third of nucleus lateralis	Pre- and post-central gyri, precentral fibres only go to operculum; post-central much fewer, stop opposite lower end of intra-parietal sulcus	Nil	Nil	Nil	Lesion. Nil	Nil ... ...

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere	Remarks
Nil	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.

Lateralis (B) *Middle Third.*

Nil	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Nil	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Nil	Nil	Nil	Nil	Nil	Fibres to anterior colliculus; these are pallio-tectals cut across in their passage through nucleus ventralis	Needle introduced horizontally.

Lateralis (C) *Ventral Third.*

Nil	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 216	In nucleus arcuatus and cutting the lower edge of centre median	Nil	Nil	Fibres break up here	Fine fibres break up in upper part of lateral nucleus. In addition some of superior; peduncular fibres can be seen degenerated	Fine fibres break up here	Fine fibres break up here
Rh. 218	In nucleus arcuatus cutting lower edge of centre median	Nil	Nil	Fine fibres break up here	Fine fibres break up here	Fine fibres break up here	Fine fibres break up here
Rh. 275	In centre median ...	Nil	Nil	Nil	Fine fibres break up here	Nil	Nil .. ...
Rh. 267	In centre median and on border between it and nucleus lateralis (ventral portion)	Nil	Nil	Nil	Some fibres enter nucleus lateralis and break up in its inner half, extending over an area corresponding to the sectional area of lesion	Fine fibres break up here	Fine fibres break up here
Rh. 87	In lower part of centre median and nucleus arcuatus, partly in ventralis and cutting Meynert's bundle	Indeterminate..	Nil	Fine fibres break up here coming up from lesion	Fibres go into posterior ventral fourth and into ventral border of superior nucleus and pulvinar	Fine fibres break up here	Lesion; fine fibres break up here

Lesions of

Rh. 203	In the trunk of median fillet posteriorly where it comes around the nucleus ruber and extends to beginning of corpus Luysii. In breadth nowhere exceeds the breadth of fillet	Indeterminate...	Nil	Nil	A few fillet fibres end here	Most of the fillet fibres break up here	Nil ... ...

and Nucleus Arcuatus.

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere	Remarks
Lesion ...	Fibres break up here	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Lesion ...	Fibres to pulvinar	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Lesion fibres run down into nucleus arcuatus	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Lesion ...	Nil	Nil	Nil	Nil	Nil	Needle introduced horizontally.
Lesion; fibres pass through nucleus arcuatus and end in reticular area	A few fibres end here	Nil	The posterior longitudinal bundle is degenerated in part. Fibres are seen ending in nuclei of cranial nerves (V, VI, VIII, X)	Nil	Fibres run from lesion in Forel's field and end in globus pallidus; Meynert's bundle degenerated to interpeduncular ganglion	Needle introduced vertically.

Hypothalamus.

Nil	Nil	Fine fibres go to capsule of lower part of homolateral nucleus and to the contralateral nucleus ruber	Nil	Nil	Nil	Needle introduced horizontally and passed along the course of the median fillet. On account of bruising of the cortex in removing the brain the cortex was not examined; however, the internal capsule was clear and contained no degeneration.

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 207	Lower part of ventral nucleus and upper border of Forel's field anteriorly cuts the lower end of the fan-shaped distribution of the fillet	Operculum? ...	Nil	Nil	Fillet fibres break up here	Fillet fibres break up here	A few fibres end herein

Lesions of

Rh. 236	Large lesion, central focus of which is in posterior limb and outer part of genu of internal capsule, also destroys anterior superior mesial third of the lateral nucleus; edge of anterior nucleus, of nucleus medius, of caudate and tænia thalami	A few very fine fibres to frontal gyri; coarser fibres to pre- and post-central gyri; fewer and finer fibres to post-central gyrus	A few fine fibres	A few fine fibres break up herein	Large bundles of fine fibres entering anterior and middle third (fronto-thalamic lenticulo-thalamic)	Some fibres in this nucleus in both hemispheres	Some fibres break up herein
Rh. 258	In internal capsule in front of and to outer side of nucleus anterior needle track passes through dorsal part of nucleus lateralis	Fine fibres to inferior and middle frontal gyri; a few coarser fibres from needle track to pre- and post-central gyri	Nil	Nil	Lesion ...	Nil	Nil ... ...
Rh. 251	Anterior limit is in most basal part of capsule just behind the genu. Posterior limit in Forel's field on a level with centre of corpora mammillaria	Nil	Nil	Nil	Fillet fibres break up herein	Fillet fibres break up here	Fine fibres to ventral nucleus and break up herein

Lesions of

Cat 91	Pulvinar and anterior colliculus	Indeterminate ...	Indeterminate ...	Indeterminate	Indeterminate	Indeterminate	Indeterminate

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere	Remarks
A few to centre median; most seem to end in nucleus arcuatus	Nil	A few break up here	Nil	Nil	Medium-sized fibres to globus pallidus	Needle introduced horizontally.
Capsula Interna.						
Nil	Nil	Nil	Nil	Pyramidal degeneration	A few fine fibres to caudate and globus pallidus and middle zone of nucleus lenticularis. Fibres in Schultze's bundle	This lesion was made large with the idea of producing symptoms. It was, however, anatomically not very satisfactory because of its size and the capsular injury. Needle introduced horizontally.
Nil	Nil	Nil	Nil	Pyramidal fibres from lesion of capsule	Nil	Needle introduced horizontally.
Nil	Nil	Some fibres from needle track break up here. Fibres from lesion end in anterior capsule of nucleus ruber	Tecto-pontine fibres from needle track	Nil	Some fine fibres to tuber cinereum and to locus niger, another group cross the capsule, and break up in the globus pallidus	Needle introduced horizontally. Needle track passed through the fillet.
Mesencephalon.						
Indeterminate	Lesion ...	Nil	Tecto-pontine fibres; most dorsal fibres of posterior longitudinal bundle; these latter disappear before they reach the cord	Nil	Fibres cross posterior commissure and break up in reticular substance of opposite side in plane of base of the aqueduct of Sylvius	As needle was introduced vertically the cortical injury permits only of a positive opinion being expressed on the descending fibres.

No.	Lesion	Cortical fibres	Nucleus anterior	Nucleus medius	Nucleus lateralis	Nucleus lateralis, ventral portion	Nucleus ventralis
Rh. 211	In upper nucleus of nucleus ruber	Nil	Nil	Nil	Nil	Fine fibres break up herein and in ventral part on the contralateral side	Nil ... ..
Rh. 273	Anterior part of anterior colliculus and cutting the anterior brachium and a few of the dorsal terminal fibres of the superior cerebellar peduncle	Nil	Nil	A few medium-sized fibres run here	Fine fibres break up herein	Nil	Nil ... ...

Further, the rubro-bulbar tract now described occupies the region through which also pass the fibres of the tractus recurrens of the superior cerebellar peduncle (Thomas [152], Van Gehuchten [63], Horsley and Clarke), and it also ceases in the nucleus centralis reticularis and the nucleus magno-cellularis bulbi. The tract in question may have been injured by the lesion in Ernst's [47] experiment, but at a point below the nucleus ruber.

In leaving the discussion of lesions of the hypothalamic region it is necessary to draw attention to the fact that, though the experiments reveal a close association between the nucleus ruber and the globus pallidus, there is, as regards downward directed paths, no evidence of a direct connection between the thalamic nuclei (for instance, the nucleus lateralis) and the nucleus ruber. It is evident the whole important question of the downward or efferent connection of the thalamus and nucleus ruber requires a complete re-examination and research.

Stimulation Experiments.

In the stimulation experiments the double needles mentioned in the section on "Method and Technique" were used throughout. In employing these needles a bipolar excitation could be applied to an

Centre median and nucleus arcuatus	Pulvinar	Nucleus ruber	Descending fibres to medulla and pons	Cord	Fibres elsewhere	Remarks
A few fine fibres end herein	Nil	Lesion ...	Monakow's bundle consisting of rubro-spinal and rubro-bulbar; of the former only two or three fibres. Another tract starts from anterior end of nucleus ruber, decussates in Forel's commissure and passes down just outside of medullary sheet, and apparently ends in nucleus magno-cellularis; a few fibres go down posterior longitudinal bundle	Fibres in anterior column from the posterior longitudinal bundle fibres	A very few fibres of medium size go into globus pallidus	Needle introduced horizontally.
Medium-sized fibres break up in upper and posterior part of centre median	Nil	Nil	Tecto-ponto-bulbar tract. These fibres run down the same side near the median line and break up in the substance of the pons	Nil	Pallio-tectal fibres	Needle introduced horizontally.

extremely small area, and thus the disconcerting and disturbing effects of unipolar stimulation were avoided. This point has been dwelt on in the foregoing pages, and at considerable length in Horsley and Clarke's article on the cerebellum in *Brain*, 1908. In order to obtain the most precise results the smallest double needles we had were used, and these measured on the average 1·5 mm. in diameter at the widest part of the collar.

The current was obtained from an induction coil which was supplied by two dry-cell batteries. The secondary coil was furnished with the Kronecker scale which, though it does not indicate the actual quantity of current used, shows the relative proportionate excitation—*i.e.*, if the coil is at 200 on the scale, and then is advanced to 400, the stimulus obtained at the latter position is twice that obtained at the first. The average strength of current used varied from 100-500 Kronecker scale divisions, and if any region was found to be inexcitable, this was further tested by raising the intensity of the stimulation until "spread" evoked a response from neighbouring structures.

In this respect, as in all excitation experiments, the mode of response clearly indicated what was the real local effect of the stimulus.

In the procedure of these experiments, which were all carried out on *Macacus rhesus*, the monkey—thoroughly anæsthetized—was placed in Clarke's instrument, and after the skull and dura had been opened the double needle was introduced usually 2 mm. at a time. Every 2 mm. a stimulation was made and the resulting phenomena recorded.

If the nerve centres did not show signs of fatigue the entire thalamus was thus stimulated. The very slight shock attending such an experiment is evidenced by the fact that good results may be obtained for two or three hours if the body temperature is not allowed to fall and the brain kept warm by a constant stream of hot water. There is no apparent change in the electrical excitability of the brain. Furthermore, the passage of these small needles produces such a slight injury to the cells that bringing back the needle to a point stimulated some time previously, and stimulating there again, yields the same results as the first time. As soon as the experiment was completed the monkey was killed and the brain injected *in situ* with formol-Müller. The inter-aural line was then marked by boring a hole through the external auditory meati and a rod dipped in carbon and oil passed through to mark the inter-aural line (*see* fig. 76, Slab 1). Other points were then marked on the cortical surfaces to establish the inter-aural plane and the brain was removed. The brain was then cut through the inter-aural plane and then further cut up into 2 mm. slabs on Clarke's macrotome.

The exact points at which the stimuli were applied could then be determined, since, as can be seen on figs. 76 *et seq.*, the fine needle track examined immediately after death in the fixed brain is obvious as a small black point in frontal section. As stated in Horsley and Clarke's [75] paper, fixed points for localization purposes were also made as required by switching off the faradic current, and marking the spot excited by a small electrolysis.

The collective results of the experiments can best be stated, in so far as they followed the excitation of the various nuclei or fibres passing through them.

Nucleus Anterior.

This region is evidently extremely inexcitable, for even powerful currents produced no effect whatsoever. When the edges of the nucleus are reached, however, the same or similar symptoms may be observed as arise from regions adjacent to the anterior nucleus.

Figs. 76-79. *Stimulation Experiment.* *Macacus rhesus.*—As seen in Slab 1, the inter-aural line passes through the trapezial region. The brain was divided into slabs 2 mm. thick, numbered 1 to 8, but was not cut quite vertically, hence the upper (thalamic) portion of Slab 2 is actually in the inter-aural or zero plane. The divisions of the scale shown are millimetres; the magnification therefore about 2·5. The needle tracks are visible as dots, but the distortion of the brain after removal from the skull alters somewhat their 2 mm. relation to each other.

FIG. 76.

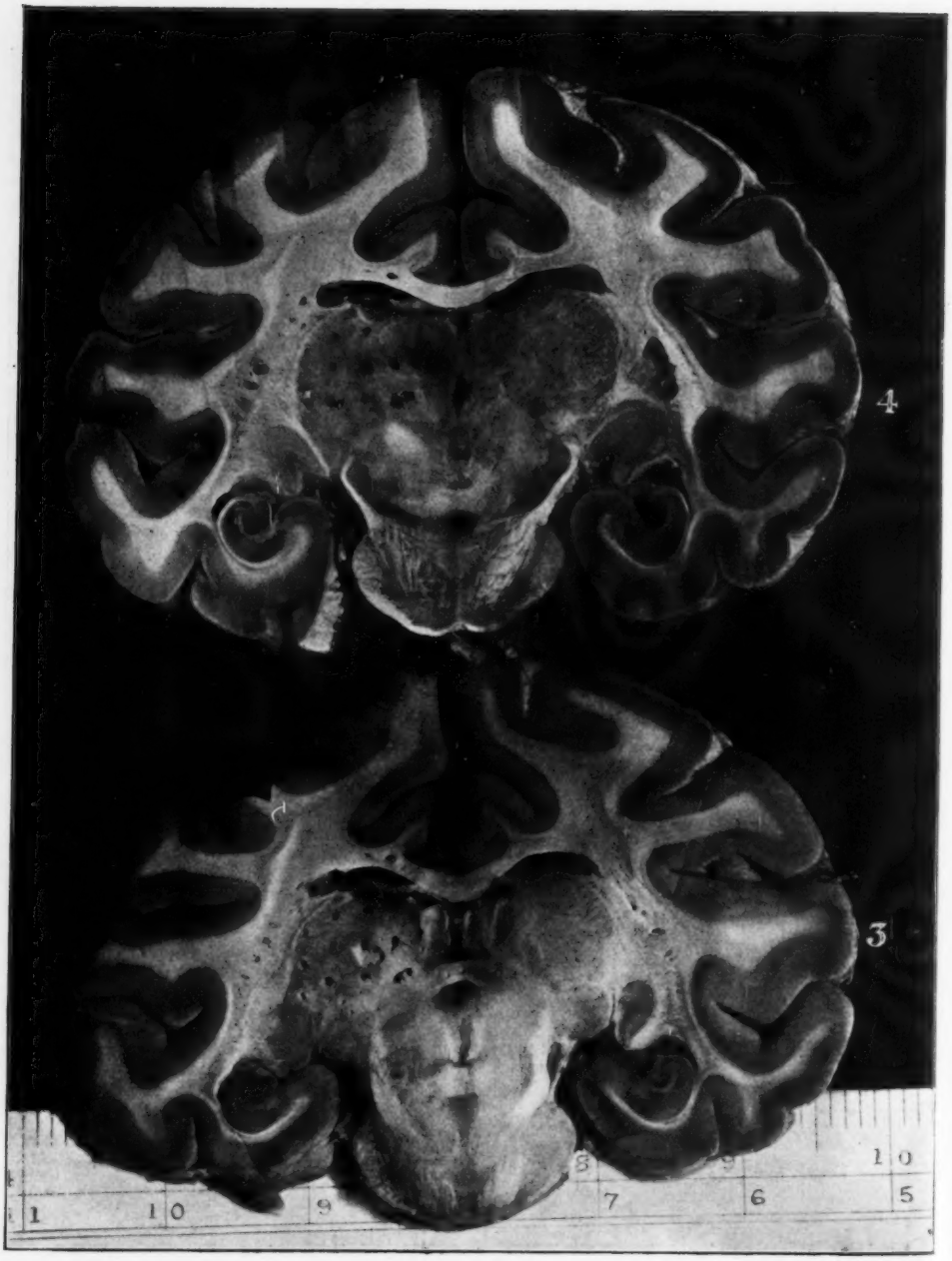


Fig. 77.

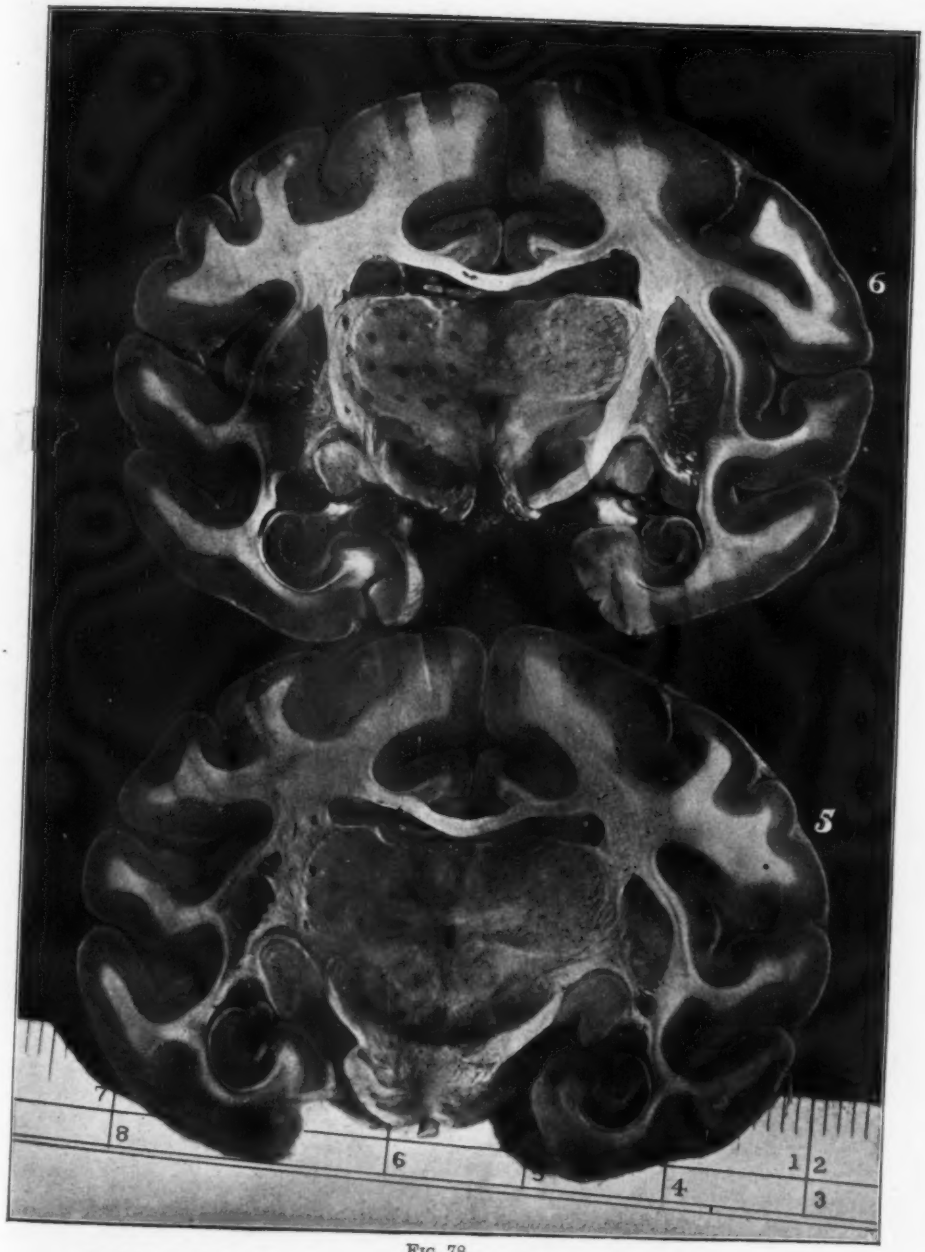


FIG. 78.

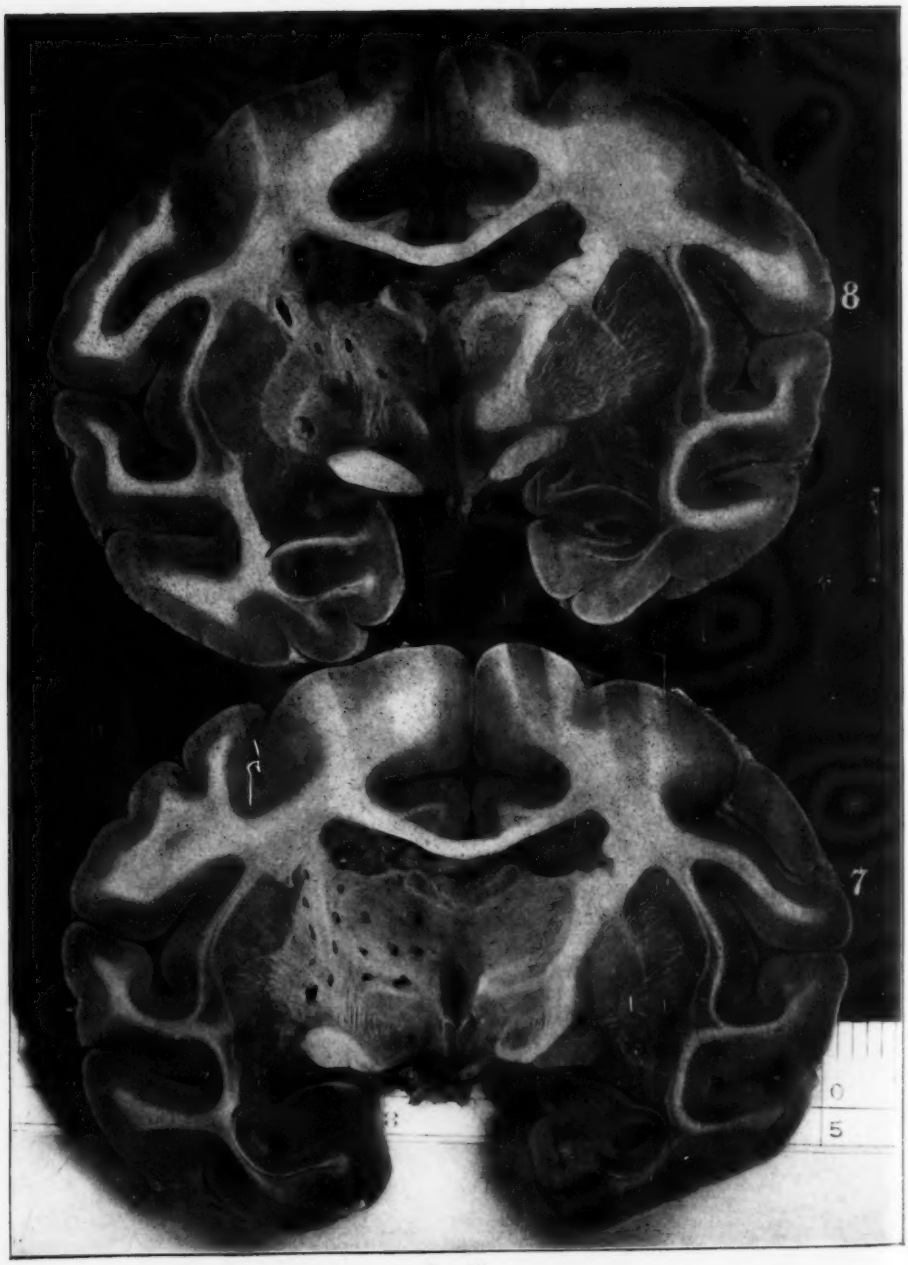


Fig. 79.

Nucleus Medius.

(*a*) The dorsal part of the nucleus, that lying directly beneath the tænia thalami, is inexcitable. When the central portions of the nucleus were stimulated, eye-movements were obtained, and these, with but occasional exceptions, consisted in the eyes being fixed with their visual axes parallel and parallel to the median sagittal plane.

Together with this there was at times dilatation of the pupils, but this was not a constant phenomenon. The appearance of the animal during excitation of the nucleus was that of attention. These movements were characterized by their comparatively slow onset, and contrast notably with ocular movements derived from any other part of the central nervous system in which the eye-muscles are represented.

(*b*) The ventral part of the nucleus is very interesting in its response to stimulation, inasmuch as, as soon as the needle advanced to and beyond the plane limiting the massa intermedia (commissura mollis) posteriorly, the excitation evoked a moderate deviation of the head and eyes to the opposite side and flexion of the opposite fore-limb. This is obviously the commencement of progression movement, as will be described by Horsley and Clarke, resulting from excitation of the fibres of the superior cerebellar peduncle (*cf.* also Thiele). These fibres have been found by the authors[1] just named to branch beneath and in the nucleus medius—*i.e.*, in the lamina interna.

Nucleus Lateralis.

Excitation of the nucleus lateralis has given constant results, but the interpretation of the effects observed requires careful consideration and merits further minute investigations in animals on whom exclusion experiments have previously been performed—*i.e.*, removal of the corresponding areas of the excitable cortex with establishment of pyramidal degeneration, &c. The present communications, therefore, will consist of a brief categorical summary of the points noted, without discussion of the detail of the probable paths taken by the nerve impulses.

Part of the Nucleus lateralis excited.	*Movement observed.*
Posterior Third Dorsal half ...	Conjugate deviation of the eyes to the opposite side.
Posterior Third Ventral half ...	Eyes open, progression movement, extension of opposite fore-limb, later flexion of fore-limb of the same side.

[1] These fibres are probably the source of the locomotory movements observed by Thiele on excitation of the cut surface of the posterior part of the median nucleus [149].

Part of the Nucleus lateralis excited.	*Movement observed.*
Middle Third Dorsal half	Movement of the opposite limbs, flexion and extension.
Middle Third Ventral half	Progression movement, facial movements of the opposite side.
Anterior Third Dorsal half	Capsular movements.
Ventral half	Head turned to the opposite side, mouth open, mastication, face contralateral movement, tongue to the opposite side, flexion both fore-limbs, most on the opposite side. Flexion both hind limbs.

It is desirable, perhaps, to repeat here that these motor phenomena constitute no evidence of special centres in the thalamus for automatic or rhythmic movements, as has been assumed by some authors.

Centre Median and Nucleus Arcuatus.

The results obtained from this region are essentially compound—*i.e.*, a summation of those obtained by excitation of the median nucleus and of the superior cerebellar peduncular fibres.

Thus in all cases a combined movement of parallelism of the optic axes, with extension of the opposite fore-limb and flexion of the elbow of the same side, resulted from stimulation of the centre median and nucleus arcuatus.

Pulvinar.

Excitation of the pulvinar invariably produced conjugate deviation of the eyes to the opposite side, with dilatation of the pupils.

In time the rate of this movement was between that obtained from the colliculus anterior and that from the median nucleus (the slowest, *v. supra*).

A special point in reference to the pupil must be mentioned here. In a constant series of observations a very sharp, quick contraction of the pupils was obtained from a spot where the outer part of the posterior commissure crosses behind Meynert's bundle. This is a direct effect of the excitation communicated to the third nucleus, and is very striking in view of the widespread representation of dilatation all round this point.

SYMPTOMS.

The symptoms observed in each animal the subject of an experimental lesion must be divided according to the site of the lesion—cortical or thalamic.

(*a*) Symptoms following lesions of the cortex cerebri.

Since the researches of Munk and Goltz attention has been sufficiently given to the symptoms which immediately follow the production of a destructive lesion due to the disturbance of an operation, and those which permanently remain as consequences of the lesion itself. In every case the transient symptoms have been noted, but need not be referred to now.

As regards permanent changes, little has been observed except in lesions of the sensori-motor area. Further, whereas the cat responds readily to all forms of sensory stimulation, the monkey is exceedingly indifferent, and the accurate estimation of sensory changes in this animal presents many difficulties. However, in all cases each animal was systematically and repeatedly examined as to motor power, co-ordination, hemianopsia, æsthesia to touch, cold, heat, pin-prick, and in the monkey also astereognosis.

(1) *Cats.*

(*a*) Sensori-motor region (*see* Table I).

Lesions of the cruciate region were followed by loss of sense of position, thermo-anæsthesia to cold and paresis of special (voluntary) movements in the contralateral limbs.

(*b*) Parieto-temporal regions (*see* Table I).

From the small lesions of the other parts of the cortex no symptoms were distinguishable.

(2) *Monkeys* (*Macacus rhesus*).

In this animal the lesions were confined to the central gyri.

(*a*) Gyrus precentralis (*see* Table I).

The monkeys with precentral lesions showed paresis of the extremity corresponding to the cortical area destroyed, and uncertainty in use of the affected limb when jumping and climbing free in a large cage.

No sensory changes could be detected. The knee-jerk of the opposite side was increased except when at a later stage contracture commenced. It was then diminished.

(*b*) Gyrus postcentralis (*see* Table I).

The monkeys with postcentral lesions were apparently quite normal. In their free movements and to every test their sensory and motor power appeared unaltered. In one case of a postcentral lesion there were symptoms of paresis and uncertainty, and this therefore appeared to

constitute an exception. The serial sections of the brain, however, showed a thrombotic lesion, low down in the corona radiata, that had cut off precentral fibres. The experiment, therefore, confirms the facts given above in differentiation between the two central gyri.

(*c*) Symptoms following lesions of the optic thalamus.

Since the earliest investigations on the thalamus down to the most recent work by Roussy two cardinal symptoms have always been recorded as characteristic of such a lesion. (1) Mouvement de manège; (2) hemianopsia.

All observers, as far as could be discovered in the literature, have noted those two symptoms, with the sole exception of Nothnagel. It must seem very surprising, therefore, that in the present research twenty-two Rhesus monkeys and four cats, all with thalamic lesions, not one showed the symptom of mouvement de manège, or anything at all suggesting it, and only four showed ocular symptoms.

Rh. 275 and Cat 91 both exhibited right-sided hemianopsia. Rh. 236 noticed threatening movements less on the right side than the left, but showed no signs of hemianopsia when taking his food or with currants strewn about the floor. Cat 95's pupils reacted sluggishly to light, but there was no evidence of hemianopsia.

The explanation of such absence of symptoms must be that the small lesions of the present research only destroyed small parts of the nuclei, and consequently that sensory representation of any given region could only have been slightly affected. That this is probably correct is shown by the fact that in one case where a considerable injury was done to the pulvinar, hemianopsia resulted, and that in the case (Rh. 211) where the lesion was situated in the nucleus ruber the opposite ear was drawn to the shoulder.

Any thalamic syndrome must consist of an arrangement of disordered function of those senses whose special thalamic regions are destroyed, and of those tracts—*e.g.*, the internal capsule, optic tract, &c. —which lie near.

Summary.

(1) The hypothalamus is essentially distinct from the thalamus.

(2) The hypothalamus is closely connected with the globus pallidus.

(3) The thalamus must be regarded as consisting of an inner and outer division, of which the inner includes the nucleus anterior and nucleus medius.

(4) The inner division is in association with the nucleus caudatus and with the rhinencephalon.

(5) The outer division is the end station of the fillet and of the superior cerebellar peduncle. It is closely connected with the Rolandic region of the pallium.

(6) From the results of excitation experiments, as well as the anatomical facts deduced from very localized lesions, the inner and outer divisions of the thalamus appear to be in the main relatively independent organizations.

(7) The precentral especially and postcentral pallium (*Macacus rhesus*) and the excito-motor area in the cat are connected by pyramidal fibres and collaterals with the middle and ventral thirds of the nucleus lateralis.

(8) The temporal pallium (cat) is connected by projection fibres and collaterals with the postero-ventral region of the nucleus lateralis, the corpus geniculatum mediale and the pons varolii.

(9) The thalami-cortical fibres connecting the nucleus lateralis with the pallium are arranged dorso-ventrally, so that those for the representation of the face are ventral to those for the limbs.

(10) The general direction of the large majority of axones, whether originating in a thalamic nucleus or passing through the thalamus, is outwards and dorsalwards.

(11) The precentral pallial area for the representation of the movements of the limbs is not connected by pallio-tectal fibres with the colliculi.

The figures illustrating this paper are furnished to show the size and position of the lesions on which the statements in the text and in Table II are founded.

The lettering throughout is the same, as follows :—

AC = commissura anterior.
AN = nucleus anterior.
BA = brachium anticum.
BP = brachium posticum.
BT = fasciculus temporo-pontalis (Türck's bundle).
C = crus.
CA* = colliculus anterior (corpus quadrigeminum superior).

* In Rh. 251 CA is by error used to denote a corpus albicantium v. mammillare.

CCA = corpus callosum.
CG = griseum centrale.
CGE = corpus geniculatum externum.
CI = capsula interna.
CL = corpus hypothalamicum (Luysii).
CM = *centre médian.* Luys.
CN = nucleus caudatus.
CP = colliculus posterior (corpus quadrigeminum inferior)
CR = corona radiata.
d = degeneration.
f = fornix longus.
FL = fillet (lemniscus medialis).
FOL = tractus areae forellii—lenticularis (see text)
FOR or FO = field of Forel.
fd = degeneration.
fdm = degeneration of pyramidal system.
GP = globus pallidus.
GPoC = gyrus postcentralis.
GPrC = gyrus precentralis.
L or l = lesion.
Li = lamina interna.
LL = lattice layer.
LN = nucleus lateralis.
ln = locus niger.
LPP = locus perforatus posticus.
LV = ventriculus lateralis.
M = fasciculus retroflexus (Meynert's bundle).
MI = massa intermedia (commissura mollis).
MN or NM = nucleus medius.
N.II = nervus opticus.
N.III = nervus tertius v. oculo motorius.
NA = nucleus arcuatus.
NL = nucleus lenticularis.
NN = nervus quartus.
n = needle track.
PCO = operculum precentralis.
PT = tractus palliotectalis.
PU or P = pulvinar.
RGP = tractus rubro-globus-pallidus.
Sc = stratum subcaudatum (see text)
SP = pedunculus cerebelli superior.
Sp = splenium.
T = tænia thalami.
TB = tractus tecto-bulbaris.
V.III = ventriculus tertius.
VA = fasciculus Vicq. d'Azyri.
VN or NV = nucleus ventralis.

Bibliography.

[1] d'Abundo. "Contributo allo studio del sistema nervoso," *Neurol. Centralbl.*, 1898, Bd. xvii, S. 68.
[2] Arnold. "Handbuch der Anatomie," Zürich, 1838-42, 1851.
[3] *Idem.* "Anatomie des Gehirns und Ruckenmark," 1838.
[4] Asher. *Corresp. Blatt. f. schweiz. Aerz.*, 1901, Bd. xxxi., S. 461.
[5] Balfour. "Comparative Embryology," London, 1881.
[6] Baginsky. *Virchow's Archiv.*, 1886, Bd. cv., S. 28, and 1890, Bd. cxix., S. 81.
[7] Bechterew. *Neurol. Centralbl.*, 1906, Bd. xxv., S. 546.
[8] *Idem.* "Über die sensible und motorische Rolle des Sehhügels," *Monatschr. f. Psych. und Neurol.*, 1905, Bd. xvii., S. 224.
[9] *Idem. Virchow's Archiv.*, 1887, Bd. cx., S. 102.
[10] *Idem. Neurol. Centralbl.*, 1890, Bd. ix., S. 642.
[11] *Idem*, 1894, Bd. xiii., S. 252.
[12] *Idem*, 1897, Bd. xvi., S. 146.
[13] Bechterew and Mislawski, "Uber die Hirncentren der Thränenabsonderung," *Neurol. Centralbl.*, 1891, Bd. x., S. 481.
[14] *Idem*, 1888, Bd. vii., S. 505.
[15] *Idem.* "Über die Innervation des Darmes," *Arch. f. Anat. u. Physiol.* (Phys. Abth.), 1889, Suppl. Bd., S. 243.
[16] *Idem.* "Über die Innervation des Magens," *Neurol. Centralbl.*, 1890, Bd. ix., S. 173.
[17] *Idem. Archiv. f. Anat. u. Physiol.* (Phys. Abth.), 1891, S. 380.
[18] Beevor. *Phil. Trans. of the Roy. Soc.*, B., 1891, vol. clxxxii., p. 135.
[19] *Idem*, vol. cc., p. 108.
[20] *Idem* and Horsley. "On Pallio-tectal Fibres," *Brain*, 1902, vol. xxv., p. 436.
[21] Benaky. "Contribution à l'étude des fonctions de la couche optique," *Archiv. de Neurol.*, 1904, vol. xviii., p. 385.
[22] Bethe. "Anatomie und Physiologie des Nervensystems," Leipzig, 1903.
[23] Bickel. "Physiologie des Gehirns," *Pflüger's Archiv.*, 1898, Bd. lxxii., S. 190.
[24] Boyce. *Phil. Trans. of the Roy. Soc.*, B., 1895, vol. clxxxvi., pt. i., p. 321.
[25] Bruce. "Tracts of Mid and Hind Brain," Edinburgh, 1892.
[26] Burdach. "Bau und Leben des Gehirns," Leipzig, 1819.
[27] Cajal. "Las fibras nerviosas de origen cerebral del talamo optico," Fourteenth International Congress of Medicine, Madrid, 1903, Sect. Anat., p. 36.
[28] *Idem.* "Textura del sistema nervioso," 1902.
[29] Campbell. "Histological Studies on the Localization of Cerebral Function," Cambridge, 1905.
[30] Carpenter. "Principles of Physiology," London, 1851.
[31] Carville and Duret. "Sur les fonctions des hemisphères cérébraux." *Archiv. de Physiol.*, 1875, vol. vii., p. 352.
[32] Castellino. "Ueber die Function des Thalamus," *Wien. med. Wochenschr.*, 1895, Bd. xlv., S. 1395.
[33] Collier and Buzzard. "Descending Mesencephalic Tracts, &c.," *Brain*, 1901, vol. xxiv., p. 177.
[34] Contjean et Tissot. "Sur l'excitation des centres cérébraux," *Compt Rend. Soc. de Biol.*, 1897, 10me sér., vol. iv., p. 113.
[35] Couty. "Lésions du cerveau chez le chien et le singe," *Compt. Rend. Soc. de Biol.*, 1881, 7me sér., vol. iii., p. 75.
[36] Dana. "Functions of the Corpora Striata," *Journ. of Nerv. and Ment. Dis.*, 1908, vol. xxxv., p. 65.
[37] Darkschewitsch. *Neurol. Centralbl.*, 1885, Bd. iv., S. 100.
[38] *Idem* and Pribytkow. *Neurol. Centralbl.*, 1891, Bd. x., S. 417.

[39] DEITERS. "Untersuchungen über Gehirn u. Rückenmark," Braunschweig, 1865.
[40] DEJERINE. "Anatomie des centres nerveux," Paris, 1895, 1901.
[41] *Idem* and LONG. "Sur les connexions de la couche optique avec la corticalité cérébrale," *Compt. Rend. Soc. de Biol.*, 1898, 10me sér., vol. v., p. 1131.
[42] DUPUY. "Leçons sur les fonctions du cerveau," *Soc. de Biol.*, 1884.
[43] EDINGER. *Neurol. Centralbl.*, 1893, Bd. xii., S. 327. *Archiv. f. Psychiat.*, 1895, Bd. xxvii., S. 950.
[44] *Idem*. "Vom Verlauf der Gefühlsbahnen," *Deutsch. med. Wochenschr.*, 1890, Bd. xvi., S. 421.
[45] *Idem*. "Vorlesungen über das Centralnervensystem," Bd. i. and ii., Leipzig, 1904, 1908.
[46] EISENLOHR. "Zur Hirnlocalisation," *Deutsch. Zeitsch. f. Nervenheilk.*, 1893, Bd. iii., S. 260.
[47] ERNST. "On the Descending Tracts from the Thalamus and Anterior Corpora Quadrigemina." Dissertation (Russian), St. Petersburg, 1902.
[48] FERRIER. "Functions of the Brain," London, Second Edition, 1886.
[49] *Idem* and TURNER. *Phil. Trans. of the Roy. Soc.*, B., 1898, vol. cxc., p. 1.
[50] FLATAU and JACOBSON. "Vergleichende Anatomie," Berlin, 1899.
[51] FLECHSIG. "Leitungsbahnen in Gehirn," 1876.
[52] *Idem*. *Neurol. Centralbl.*, 1897, Bd. xvi., S. 290.
[53] *Idem*. *Arch. f. Anat. u. Physiol.* (Anat. Abth.), 1881, S. 12.
[54] FLOURENS. "Recherches expérimentales sur les fonctions du système nerveux," Paris, 1842.
[55] FOREL. "Untersuchungen über die Haubenregion und ihre oberen Verknüpfungen, &c." *Arch. f. Psych.*, 1877, Bd. vii., S. 393.
[56] *Idem*. "Einige Hirnanatomische Ergebnisse," *Arch. f. Psych.*, 1887, Bd. xviii., S. 162.
[57] FOVILLE. "Traité de l'Anatomie du système nerveux," Paris, 1844.
[58] FOURNIÉ. "Recherches sur les fonctions du cerveau," Paris, 1873.
[59] FRANCE. *Phil. Trans. of the Roy. Soc.*, B., 1889, vol. clxxx., p. 331.
[60] FROIN. "Etude des localisations dans les noyaux gris," *Compt. Rend. Soc. de Biol.*, 1903, vol. lv., p. 1657.
[61] GANSER. "Anatomische Studie über das Gehirn des Maulwurfs," *Morphol. Jahr.*, Bd. vii., S. 591.
[62] GEHUCHTEN, VAN. "L'anatomie du système nerveux de l'homme."
[63] *Idem*. "Névraxe," 1903, vol. v., p. 263; 1905, vol. vii., p. 29.
[64] GENTES and AUBARET. "Connexion de la voie optique," *Compt. Rend. Soc. de Biol.*, 1902, vol. liv., p. 1283.
[65] GOLTZ. *Pflüger's Archiv.*, 1881, Bd. xxvi., S. 1; 1882, Bd., xxviii., S. 579; and 1888, Bd. xxxiv., S. 451.
[66] GOWERS. "Case with Lesion in Optic Thalamus," *Journ. Neurol.*, 1892.
[67] GUDDEN. *Arch. f. Psych.*, 1870, Bd. ii., S. 693.
[68] HALE WHITE. "Rise of Temperature from Lesions of Thalamus," *Brit. Med Journ.*, 1889, vol. i., p. 1401.
[69] HAMILTON. *Proc. Roy. Soc.*, 1884, vol. xxxvi., p. 349.
[70] HELD. *Arch. f. Anat. u. Physiol.*, 1891 (Anat. Abth.), S. 271, and 1893 (Anat. Abth.), S. 201.
[71] HENLE. "Anatomie des Menschens," Braunschweig, 1868.
[72] HITZIG. *Arch. f. Psych.*, 1903, Bd. xxxvi., S. 1.
[73] HORSLEY and SCHÄFER. *Proc. Roy. Soc.*, 1884, vol. xxxvi., p. 437.
[74] *Idem*, 1885, vol. xxxix., p. 404.
[75] *Idem* and CLARKE. *Brain*, 1908, vol. xxxi., p. 1.
[76] HOSEL. "Ueber die Markreifung der Körperfühlsphere," *Arch. f. Psych.*, 1905, Bd. xxxix., S. 195.
[77] IRWANOW. Dissertation, St. Petersburg, 1899.
[78] JACKSON. "Functions of Optic Thalamus," *Clinical Lectures and Reports of London Hospital*, 1866, vol. iii., p. 373.
[79] JELGERSMA. *Neurol. Centralbl.*, 1895, Bd. xiv., p. 290.

[80] KIRCHOFF. "Ein mimisches Centrum im medialen Kern des Sehhügels," *Arch. f. Psych.*, 1902, Bd. xxxv., S. 814.
[81] *Idem.* *Arch. f. Psych.*, 1897, Bd. xxix., S. 888.
[82] KIRILZEW. *Neurol. Centralbl.*, 1891, Bd. x., S. 405.
[83] KÖLLIKER. "Anatomie des Nervensystems."
[84] KOHNSTAMM and QUENSEL. *Neurol. Centralbl.*, 1908, Bd. xxvii., S. 242.
[85] LAFFORGUE. "Etude sur la lesion de la couche optique," Paris, 1877.
[86] LANGLEY und GRÜNBAUM. *Journ. Physiol.*, 1890, vol. xi., p. 606.
[87] LENHOSSEK. *Neurol. Centralbl.*, 1894, Bd. xiii., S. 412.
[88] LEWANDOWSKY. "Die Functionen des Nervensystems," Jena, 1907.
[89] LO MONACO. *Arch. Ital. de Biol.*, 1898, vol. xxx., p. 198.
[90] *Idem.* *Neurol. Centralbl.*, 1901, Bd. xx., S. 118.
[91] LONG et ROUSSY. "Hémianesthésie cérébrale par lésion de la couche optique," *Revue Neurolog.*, 1906, vol. xiv., p. 1202.
[92] LONGET. "Anatomie du système nerveux," 1846.
[93] LUCIANI. "Das Kleinhirn," Leipzig, 1893.
[94] LUSSANE and LEMOIGNE. *Arch de Physiol.*, 1877, vol. ix., p. 119.
[95] LUYS. "Sur le système nerveux," Paris, 1865.
[96] MAGENDIE. "Le système nerveux," Paris, 1841.
[97] MANN, G. "On the Optic Thalamus," *Brit. Med. Journ.*, 1905, vol. ii., p. 289. ✓
[98] MARBURG. "Atlas des menschlichen Gehirns," 1904.
[99] MARINESCO. "Des connexions du corps strié," *Compt. Rend. Soc. de Biol.*, 1895, 10me sér., vol. ii., p. 77.
[100] *Idem.* *Semaine Méd.*, vol. xvi., 1896, p. 214.
[101] MARCHI. "Sulla strutura dei thalami ottici," *Rivist. sper. di fren.*, 1884, vol. x., p. 329; *ibid*, 1886, vol. xii., p. 285.
[102] MAY, P. "Degenerations in Posterior Columns of Cord," *Rev. of Neurol. and Psych.*, 1905, vol. iii., p. 1.
[103] *Idem.* Referred to by MANN, G. (*see* above).
[104] MEYNERT. *Wien. med. Jahrsb.*, 1872, Bd. ii., S. 188.
[105] *Idem.* "Psychiatrie," Wien., 1884.
[106] MOELI und MARINESCO. *Arch. f. Psych.*, 1892, Bd. xxiv., S. 655.
[107] MONAKOW, VON. "Untersuchungen über den Thalamus opticus, &c.," *Arch. f. Psych.*, 1895, Bd. xxvii., S. 1, 386.
[108] *Idem.* *Arch. f. Psych.*, 1882, Bd. xii., S. 141, 535.
[109] MONAKOW. "Gehirnpathologie," "Nothnagel Specielle Pathologie und Therapie," Wien, 1897, Bd. ix., Th. 1.
[110] MOTT. *Brain*, 1895, vol. xvii., p. 1.
[111] MUNK. "Über die Funktionen des Grosshirns," Berlin, 1890.
[112] MÜNZER und WIENER. "Das Gehirn des Kaninchens," *Monatschr. f. Psych.*, 1902, Bd. xii., S. 241.
[113] MURATOFF. *Neurol. Centralbl.*, 1893, Bd. xii., S. 714.
[114] NISSL. "Die Kerne des Thalamus beim Kaninchen," *Neurol. Centralbl.*, 1889, Bd. viii., S. 549.
[115] NOTHNAGEL. "Untersuchungen am Gehirn," *Virchow's Archiv.*, 1874, Bd. lxii., S. 201.
[116] *Idem.* *Virchow's Archiv.*, 1873, Bd. lviii., S. 420.
[117] OBERSTEINER. "Nervöse Centralorgane," Leipzig u. Wien, 1901.
[118] OPPENHEIM. "Lehrbuch der Nervenkrankheiten," Berlin, 1905.
[119] OTT. "Vaso-tonic Centres in the Thalami," *Journ. of Nerv. and Ment. Dis.*, 1891, vol. xvii., p. 483.
[119A] PAGANO. *Archives Italiennes de Biologie*, 1902, vol. xxxviii., p. 299.
[120] PAVLOW. "Le Névraxe," 1900, vol. i., p. 235.
[121] PICK and KAHLER. "Neue Untersuchungen uber das Nervensystem," *Arch. f. Psych.*, Bd. x., 1880, S. 179, 297.
[122] PREISIG. *Journ. f. Psychol. u. Neurol.*, 1904, Bd. iii., S. 215.
[123] PROBST. *Monatschr. f. Psych.*, 1900, Bd. vii., 387, and 1900, viii., 165.

[123A] *Idem*, 1901, Bd. x., S. 288.
[124] *Idem*. *Deutsch. Zeit. f. Nervenheilk.*, 1900, Bd. xvii., S. 141.
[125] *Idem*. 1898, Bd. xiii., S. 384.
[126] *Idem*. *Arch. f. Psych.*, 1900, Bd. xxxiii., S. 721.
[127] *Idem*. 1902, Bd. xxxv., S. 22.
[128] *Idem*. *Wien. klin. Wochenschr.*, 1902, Bd. xv., S. 932.
[129] *Idem*. *Sitz. der Wien. Akad. der Wissensch.*, 1905, Bd. cxiv., Abth. iii., S. 173.
[130] PRUS. "Electrische Reizung des Thalamus opticus," *Wien. klin. Wochenschr.*, 1899, Bd. xii., S. 1199.
[131] RETHI. "Die Nervenwurzeln des Rachens, &c.," *Sitzb. d. Wien. Akad. d. Wissensch.*, 1893, Bd. cii., Abth. iii., S. 201.
[132] RETZIUS. "Das Gehirn des Menschens," Stockholm, 1896.
[133] ROTHMANN. "Versammlung der Deutsch. Naturforscher Gesellschaft," Dresden, 1907, Teil ii., 2 halfte, S. 205.
[134] RICHTER. "Zur Frage der Optischen Leitungsbahnen," *Arch. f. Psych.*, 1885, Bd. xvi., S. 639.
[135] ROUSSY. "La couche optique," Paris, 1907.
[136] SACHS. "Das Hemispherenmark," Breslau, 1892.
[137] SACHS. "Eine vergleichende anatomische Studie des Thalamus opticus der Säugetiere." Arb. aus d. Neurol. Instit. [Obersteiner], 1908, Bd. xvii., Hft. 2, S. 280.
[138] SCHWALBE. "Lehrbuch der Neurologie," 1881.
[139] SCHIFF. "Experimentelle Physiologie," Florence, 1873.
[140] SELLIER et VERGER. "Lésions de la couche optique," *Compt. Rend. Soc. de Biol.*, 1898, 10me sér., vol. v., p. 522.
[141] *Idem*, 1903, 11me sér., vol. v., p. 485.
[142] *Idem*. "Recherches sur la physiol. de la couche optique," *Arch de Physiol.*, 1898, vol. xxx., p. 706.
[143] SERRES et LOUSTAN. "Anatomie du cerveau," Paris, 1824.
[143A] SIMPSON. *Proc. of the Physiolog. Soc.*, 1901-2, July 20, p. x.
[144] SHERRINGTON and GRÜNBAUM. *Proc. Roy. Soc.*, 1901, vol. lxix., p. 206.
[145] SOURY. "Fonction du cerveau," 1892.
[146] SPITZKA. *Neurol. Centralbl.*, 1885, Bd. iv., S. 246.
[147] STARR. *Journ. of Nerv. and Ment. Dis.*, 1884, vol. xi., p. 327.
[148] TARASEWITCH. "Untersuchung über Thalamus, &c.," Arbeit. aus dem Neurol. Institut, Obersteiner, Wien, 1902, H. ix.
[149] THIELE. "Thalamus and Deiter's Nucleus," *Journ. of Physiol.*, 1905, vol. xxxii., p. 358.
[150] TRAPIEZNIKOW. "Ueber die centrale Innervation des Schluckaktes. Diss. Inaug. an d. Petersbg. militärärztl. Academie." [Referat—*Jahresber. ü. Neurol. u. Psychiat.*, 1897.]
[151] TSCHERMAK. "Ueber die aufsteigende Hinterstrang-Sbahn," *Arch. f. Anat. u. Physiol.*, 1898, S. 291.
[152] THOMAS. *Journ. de Physiol.*, 1899, vol. i., p. 47.
[153] VEYSIERRE. "Recherches sur l'hémianesthésie de cause cérébrale," *Thèse de Paris*, 1874.
[154] VICQ D'AZYR. "Recherche sur la structure de cerveau," Paris, 1805.
[155] VOGT. "Faisceau septo-thalamique," *Compt. Rend. Soc. de Biol.*, 1898, Sér. 10, v., p. 206.
[156] WALLENBERG. "Ueber centrifugale Bahnen aus dem Sehhügel," *Neurol. Centralbl.*, 1901, Bd. xx., S. 50.
[157] WERNICKE. "Gehirnkrankheiten," Kassel, 1881.
[158] ZACHER. *Arch. f. Psych.*, 1891, Bd. xxii., S. 654.
[159] ZIEHEN. "Zur Physiol. der Infracorticalen Ganglien, &c.," *Arch. f. Psych.*, 1890, Bd. xxi., 863.
[160] *Idem*. "Anatomie des Nervensystems," Jena, 1902.
[161] *Idem*. "Untersuchungen über die Marsupialier," 1901.

MYOTONIA ATROPHICA.

BY FRED E. BATTEN AND H. P. GIBB.

Introduction.

The object of this paper is to draw attention to a group of cases which present the rare association of muscular atrophy with a slow relaxation of muscles after voluntary contraction. The muscular atrophy has a distribution which is peculiar and corresponds to none of the well-known types of myopathy.

The characteristic features of the condition are weakness of the facial muscles (myopathic face), atrophy of the sterno-mastoids, atrophy of the vasti of the thighs and dorsiflexors of the feet, and a slow relaxation of certain muscles after contraction. The more forcible the contraction, the slower the relaxation.

We are aware that variations from the type have been described both in the distribution of the muscular atrophy and in the occurrence of the slow relaxation without atrophy, but considering the striking resemblances of our own cases, and those which we have collected from the literature, we think the type is worthy of recognition.

Name.

This condition has been described under various names: Myotonia with muscular atrophy (Lannois). Muscular atrophy with the electrical reactions of Thomsen's disease (Lortat-Jacob et Thaon). Thomsen's disease with muscular atrophy (Nogues et Sirol). Atypical forms of Thomsen's disease (Pelz). Muscular atrophy with slow relaxation of muscles (nachdauernde Muskelkontractionen) (Kleist). Myotonia atrophica (Rossolimo and others).

We have adopted that of "myotonia atrophica," first used by Rossolimo, because it serves shortly to describe the salient features, and because it is the name under which several authors have since described this condition.

We are fully aware that objection may be raised to the term *myotonia*, since it is often used as synonymous with Thomsen's disease (myotonia congenita). Myotonia is, however, only a symptom, and, as such, its use is here justified. Objection to the term "atrophica" may be raised, since the atrophy does not always occur in the muscles which exhibit the myotonia; and it may further be urged that the name implies that the myotonia precedes the muscular atrophy, a sequence of events which does not occur in all cases.

Whilst recognizing these objections, we are of opinion that fuller recognition for this condition as an entity will be obtained by such a name as above suggested than by a lengthy title, which possibly may attain to slightly greater accuracy.

Case 1.—F. W., male, aged 40. This patient came under observation in 1906, and was shown before the Neurological Society as a "case of myopathy, exhibiting slow relaxation of muscles after muscular action." Since then there has been little alteration in his condition. He gave the following history:—

In 1900 he noticed that his thighs were getting thin. The wasting caused him no inconvenience till 1903, when at times his knees would suddenly give way in walking, and he would fall. This difficulty in walking has persisted till the present time (1908). Recently he has had a stiffness about his legs, when he first starts walking, which passes off when he has gone a few yards. He complains, too, of a stiffness in the thighs when tired and of sharp shooting pains down both thighs and in small of the back. For the last few years he has noticed a steadily increasing weakness in his grip. The heavy work he is called on to do demands considerable strength, and he finds that he cannot grasp things as firmly as he could. He thinks, too, that of recent years there has been some general wasting of the forearms, especially along their ulnar borders.

For many years—he cannot say definitely how long—he has had difficulty in relaxing his grasp. He is certain the difficulty existed ten or twelve years ago. The difficulty passes off after repeated movements.

Since 1900—though here again he cannot date the onset very definitely—he has had difficulty in articulating his words when he first starts speaking. He has also had some stiffness about the jaws in chewing, and has noticed a tendency for his tongue to become stiff and "stick to the roof of his mouth" when he attempts to swallow. He has been aware of no increase in the severity of these symptoms; they are much as they were when they first came on.

Past history.—He has always been a healthy man, has suffered from no acute illnesses, and denies venereal disease.

Family history.—Both parents were healthy and had no sign of myotonia and no muscular wasting. Two children died as babies—one of whooping-cough, one of bronchitis. One child was stillborn. Two other members of

the family survived till adult life. One of these, a sister, is the second of our cases. The other, a brother, died at the age of 47 of some wasting disease of the lower limbs, which, according to his brother, was diagnosed as "locomotor ataxia." He is said to have walked with a steppage gait and to have had especial difficulty in getting up and down stairs. He constantly complained of sharp, shooting pains in the legs, but his gait was not unsteady, even in the dark. For a great many years before his death he had the same difficulty in relaxing his grasp as that of which his brother now complains. It seems probable that he suffered from the disease which now affects his brother, and this probability is heightened by the case recorded by Rossolimo, in which the diagnosis of tabes dorsalis had been made on the strength of similar symptoms.

Present condition.—He is a thin, spare man of small frame. The pupils are equal and regular; they react well to light and on convergence. All ocular movements are of good range and there is no ptosis or nystagmus. The face is strikingly smooth and expressionless. The orbiculares palpebrarum are very weak and there is some weakness of the orbicularis oris. Attempts to keep the eyes closed against even very slight resistance are unsuccessful, and he cannot whistle or blow his cheeks out properly. The temporal regions are hollowed out, the temporal muscles being apparently diminished in bulk and contracting feebly; the masseters, however, contract well and are not wasted. The tongue and palate are normal and the vocal cords move well. Both sterno-mastoids are completely atrophied, but all the other muscles of the neck are well developed.

The muscles of the shoulders and upper arms are neither wasted nor hypertrophied and all movements at the shoulders and elbows are good in range and power. There is some wasting of the whole forearm in both limbs, especially along their ulnar borders. Flexion and extension at the wrist are feeble, but the grip is fairly good. There is no wasting of any of the small hand muscles and their power is not diminished. When the patient is asked to grasp an object he does so quickly and with fair force, but when he is told to let go there is a considerable pause before he is able fully to relax or extend the fingers. The first and second fingers extend first and these are followed, after an interval of some seconds, by the third and little fingers. The difficulty in extending the fingers is due to the slow relaxation of the flexor tendon and not to any weakness of the extensors. If the patient is now asked to repeat this movement, he does so well and relaxation is more rapidly accomplished, and by repeating the movement several times he is able to relax his grasp at once. If he simply flexes the fingers without force he is able to relax at once. The stronger the original grasp the slower the relaxation.

This slow relaxation is not well shown in any muscle, except the flexors of the fingers, but is present to a slight degree in the small muscles of the hand. The biceps, however, contracts powerfully and relaxes at once.

The muscles of the trunk and abdomen are intact. In the thighs there is almost complete atrophy of the vastus internus, and a less advanced atrophy of the vastus externus in both limbs, but in both limbs the rectus femoris has escaped atrophy. There is no wasting of any other muscles of the thighs, or of the muscles below the knees.

The range and power of all movements at the hip and ankle are good.

Flexion at the knee is powerful, but extension is greatly impaired.

The gait is normal, so far as we could observe, in spite of the before-mentioned complaint of a feeling of stiffness in the movements of the lower limbs when he first starts walking. There are no sensory changes. The knee-jerks are absent in both limbs, but the ankle-jerks are active. The plantar responses on both sides are flexor.

Electrical reaction.—The most striking feature with regard to the electric reactions is the very marked diminution of irritability of the muscles generally to the faradic current. It requires a far stronger current to produce a contraction in the muscles of the patient than in corresponding muscles of the normal individual. On first stimulating the flexor muscles of the fingers there is a brisk contraction and a relatively slow relaxation. We have been unable to time the period of relaxation, but it is probably about three to five seconds.

The interossii also showed the slow relaxation.

The leg muscles needed a stronger current than normal to produce a contraction, but relaxation was quick.

To galvanism, again, a general diminution of excitability was noticed, but no other change was present. On the face he could not bear a current strong enough to produce a contraction of the muscles.

The muscles did not give the myotonic reaction as described by Erb in Thomsen's disease.

Case 2.—A. L., aged 46, sister of the above. This patient, who has been otherwise a strong, healthy woman, states that as long as she can remember she has had a difficulty in relaxing her grasp. The condition was most pronounced when she was 20 years old; since then it has improved somewhat. She is subject, too, to a difficulty in opening her eyes the first thing in the morning, and to a stiffness of the jaws in eating. This difficulty has in great part passed off during the last few years.

Present condition.—The patient is a well-nourished, healthy woman. The pupils are equal and regular, they react briskly to light and on convergence. The ocular movements are good. There is no ptosis or nystagmus.

The masseters and temporals are not wasted, and their power is good.

The face is smooth and expressionless, and there is a great weakness of the orbiculares palpebrarum. The orbicularis oris is normal. The tongue, palate and vocal cords are unaffected.

Both sterno-mastoids are completely atrophied, but the other muscles of the neck are intact. The muscles of the shoulders, arms, forearms, hands, trunk, and lower extremities are well developed and of good power. Nowhere is there any hypertrophy. Sensation is intact.

The knee-jerks and ankle-jerks are active; the plantar reflexes give a flexor response. The gait is natural.

She has precisely the same difficulty in relaxing her grasp as her brother, but does not show myotonic symptoms in any other muscles, though she gives

a definite history of difficulty in opening her eyes in the morning. We were unable to examine the electrical reactions in this case.

Case 3.—H. F., male, aged 56. This patient came under observation at the National Hospital in May, 1908, having been referred to one of us (F. E. B.) for an opinion. He had been shown at the Laryngological Section of the Royal Society of Medicine on May 1, 1908, for abductor paralysis of the right vocal cord, by Mr. Clayton Fox.

The patient gave the following history of his condition: For many years he has had a difficulty in relaxing his grasp. He cannot date the onset of this difficulty; he can only say that he has had it a great many years, but that he did not suffer from it in childhood. He has, and has had for many years, some difficulty in first starting out to walk in the morning, which soon passes off, and is not felt again during the day. He thinks the difficulty is due to an unsteadiness, rather than a stiffness in his limbs.

For some years he has had a difficulty in walking down stairs. No definite history of the date of onset of the muscular wasting can be obtained.

In December, 1907, he had an acute illness, which was diagnosed as congestion of the liver, and following immediately on this he noticed a difficulty in speaking. For this speech trouble he consulted Mr. Clayton Fox, who found an abductor palsy of the right vocal cord, and referred him to Dr. Batten for an opinion.

Past history.—He had a cellulitis of the forearm thirty years ago and erysipelas of the face ten years ago. He denies venereal disease, has always been a non-smoker, and for the last forty years a total abstainer. He has been married many years, but has no children.

Family history.—His father, who had no muscular wasting, or signs of myotonia, died at the age of 64 of a tumour of the gut. His mother had throughout her life a difficulty in relaxing her grasp, which improved as she grew old: she had no muscular wasting and died at the age of 82 of "senile decay." He has had two brothers and two sisters. Both sisters are dead, one as an infant, one in adult life of some unknown cause. One brother died at the age of 52 from bronchitis, one is still alive and in good health. None of his brothers or sisters had myotonic symptoms or muscular atrophy. He knows nothing about any other relatives.

Present condition.—The patient is a thin, old-looking man with a myopathic facies. The pupils are equal and regular, and react well to light and on accommodation. All ocular movements are good in range, and there is no ptosis or nystagmus. The face is smooth and expressionless. There is great weakness of the orbiculares palpebrarum, and some weakness of the orbicularis oris. The temporal muscles can be felt to contract, but their bulk is apparently diminished. The masseters contract forcibly, and are not wasted. The tongue is protruded straight without tremor, and is not wasted. The palate moves well and equally on the two sides. There is a partial abductor palsy of the right vocal cord.

Both sterno-mastoids are completely atrophied, and there is some wasting of the upper parts of both trapezii. All movements of the head and neck are performed with fair power.

There is no wasting or hypertrophy of any muscle about the shoulders and upper arms, and all movements about the shoulders and elbows are free and of good power. Both forearms are flabby and slightly wasted, the wasting affecting the flexors and extensors to an equal degree. All movements about the wrist are of fair power. There is no atrophy of any of the small hand muscles. When the patient is asked to grasp an object, he does so well and powerfully, but when asked to relax his grasp, he does so almost at once with the first and second fingers, but the third and fourth fingers relax slowly. The condition is exactly similar to that seen in the last patient, but is less definite.

There is no obvious wasting of any of the trunk muscles, but there is a slight degree of lordosis in the lumbar and lower dorsal regions.

The thighs are well developed, except for an almost complete atrophy of the vastus internus and externus in both limbs. The rectus femoris is intact, and no other muscles of the thighs are wasted. All movements of the thigh are powerful. Flexion at the knee is powerful; but extension is very feeble. The calf muscles are flabby and large, out of proportion to the development of the general musculature of the body. The same condition of hypertrophy is observed in the anterior tibial groups in both limbs.

All movements about the ankle are of good range, but the power of all movements, especially dorsiflexion of the feet, is very poor. This loss of power is emphasized by contrast with the large bulk of the muscles.

The knee-jerk is abolished on the left side, it is present but very difficult to elicit on the right: the ankle-jerks are absent on both sides. The plantar responses are flexor.

There are no sensory changes. In walking he lifts the feet unduly high, and flings the legs far forwards. He rises from the lying posture in the manner so constantly seen in pseudohypertrophic paralysis.

Electrical reaction.—The most striking feature with regard to the electrical reaction is the definite diminution of irritability of the muscles to faradic stimulation. This is present not only in the muscles of the arms, but also in those of the legs.

The only muscle which tends to give a slow relaxation is the flexor of the fingers, and the reaction is of the type Pässler described as a modification of the myotonic reaction, *i.e.*, both slow contraction and slow relaxation.

Case 4.—F. J., male, aged 44. This patient was admitted to the National Hospital in October 1908, under the care of Dr. Risien Russell, to whom we are indebted for permission to record the case.

Two years before admission he felt, while walking, a sudden weakness in the right knee, and from that time he noticed an increasing weakness about that knee. In August, 1907, the left knee became similarly affected, and on one occasion he fell when tired. For many months he has been unable to run at

all, because of this tendency for his knees to give way under him. He has an especial difficulty in coming down stairs, which he attributes to a loss of power in the muscles about the inner side of the thighs. He has noticed no weakness about the arms or trunk, but the forearms have been wasting for years, though they seem quite strong. He has had during the last few years a difficulty in rising from the stooping posture without the help of his arms.

No history of the date of onset of the myotonic symptoms to be described could be obtained.

Past history.—He had rheumatic fever when 11 years old; this illness left his heart weak. He had pneumonia in 1892.

Nine years ago he fell unconscious on two occasions. These unconscious attacks were attributed to heart trouble, and since then he had been unable to do any hard manual labour. He denies venereal disease. He has been married eighteen years and has two healthy boys. His only other child, a girl, died at the age of 11. She was "mentally affected."

Family.—We were unable to obtain any information as regards the existence of any similar condition in any relatives.

Present condition.—He is a thin, rather wasted man. The pupils are equal and regular, and react to light and on convergence. All ocular movements are good in range. Extreme lateral movements of the eyeballs bring out occasional slow nystagmoid jerkings. The masseters are greatly wasted and contract feebly; the temples are hollowed and the temporal muscles can hardly be felt. The face is expressionless; the eyes can be closed completely, but with poor power. The lower facial muscles move well on both voluntary and emotional efforts.

The sterno-mastoids are completely atrophied on both sides; all the other muscles of the neck are well developed and powerful. Lateral and forward movements of the head are feebly performed, though the range of movement is good.

The shoulder and upper arm muscles show nowhere either atrophy or hypertrophy, and all movements at the shoulders and elbows are powerful. The muscles of the forearms, especially the extensors, are wasted. Flexion and extension at the wrist are poor in power, and the grip is feeble on both sides. The difficulty in relaxing the grasp after making a fist is precisely similar to that seen in the first case. The intrinsic hand muscles are not atrophied, and all movements of the thumbs and fingers are strongly performed.

The muscles of the trunk are unaffected. The muscles of the lower limbs are well developed, except for a complete atrophy of the vastus internus and externus in both limbs, the rectus femoris remaining intact. The muscles below the knees are well developed. All movements about the hips are of good power. Flexion at the knees is powerful in both limbs, but extension is very feeble. Dorsiflexion at the ankle is relatively not so powerful as other movements about the joint. Sensation is unimpaired.

The knee-jerk is absent in the right limb; in the left it can be obtained on

reinforcement, but does not overcome the inertia of the joint. Both ankle-jerks are active, and the plantar reflexes are flexor. The gait is normal.

Electrical examination of the muscles was not made in this case.

Case 5.—F. W., male, aged 24. This patient was in the National Hospital in 1906, under the care of Dr. Tooth. Since then he has been under the care of Dr. Farquhar Buzzard as an out-patient at the Royal Free Hospital, and was shown by him at the Neurological Section of the Royal Society of

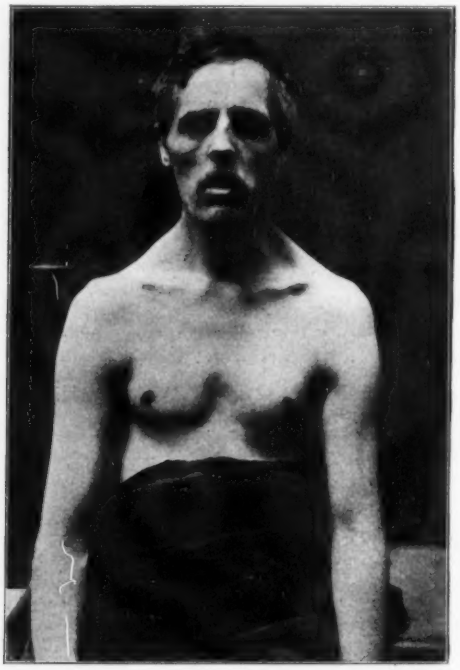


FIG. 1.

CASE 5.—Showing the atrophy of the sterno-mastoids and the myopathic facies.

Medicine as "an unusual case of muscular atrophy." To both we are indebted for the use of the clinical notes.

The patient had always enjoyed good health till the onset of his present illness. He denies venereal disease, but admits having been a heavy drinker. There is no history of muscular wasting or of myotonic symptoms in any relatives. In October, 1905, he had a severe attack of rheumatism, involving the knees, ankles, and shoulders; and when convalescent from this illness

he found that he could not walk without stepping very high. This difficulty in walking has become progressively worse. It was not until 1907 that he began to have any difficulty in relaxing his grasp.

Present condition.—The patient is a tall, spare man. The pupils are equal and regular, and react to light and on accommodation. All ocular movements are good, and there is no ptosis or nystagmus. The masseters and temporals are strong, and not atrophied. There is great weakness of the orbicularis palpebrarum, and less marked weakness of the orbicularis oris. The tongue, palate, and vocal cords are normal.

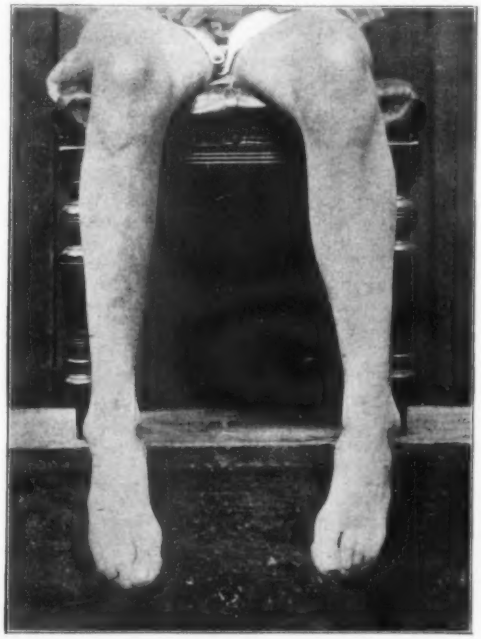


FIG. 2.

CASE 5.—Showing the moderate degree of wasting of the peronei and anterior tibial groups.

The sterno-mastoids are almost completely atrophied, but all other muscles of the neck are well developed (fig. 1). The muscles of the shoulders and upper arms are well developed and of good power (with the exception of the supra-spinati, which are considerably wasted). Both forearms are thin and wasted along their inner borders. Flexion and extension at the wrist (especially extension) are feeble and the grip in both hands is poor. The small hand muscles show no atrophy.

The muscles of the trunk are intact, as are also the muscles of the thigh, with the exception of the vastus internus, which is wasted in both limbs. The anterior tibial group are wasted, but not to an extreme degree (fig. 2). All movements of the hip and knee are of poor power. At the ankles neither dorsiflexion nor eversion can be performed. Extension is fair in power. There are no sensory changes.

The knee-jerks are present, the ankle-jerks absent. The myotonia is shown only in a difficulty in relaxing the grasp, and is precisely similar to that we have already described in Cases 1 and 4.

The muscles of the shoulder and upper arm react briskly to faradism and galvanism. The flexors of the wrist and fingers react well to faradism, but show in a marked degree the myotonic reaction. The extensors of the wrist react very poorly both to faradism and galvanism, but show no myotonic phenomena. The small hand muscles react poorly both to faradism and galvanism, and to the former give a modified myotonic reaction, *i.e.*, both slow contracture and slow relaxation. The extensors of the foot react neither to faradism nor galvanism.

Summary of Clinical Symptoms.

All these cases resemble one another closely, not only in the presence of myotonic symptoms, but also in the distribution of the atrophy. Affection of the facial musculature and atrophy of the sterno-mastoids is common to all of them. In the second case these muscles are the only ones involved, but the presence of the affection in a more advanced degree in a brother leaves no doubt as to the nature of the condition. In the remaining four cases the muscles of the shoulders and upper arms and the intrinsic muscles of the hands escape, but the forearms are affected by a general wasting, and the weakness is not confined to any particular group of muscles.

The muscles of the trunk are unaffected, but in all atrophy is present in the lower limbs. In Cases 1 and 4 the distribution of this wasting is identical—the muscles below the knee have escaped entirely, as have also the muscles of the thigh, with the exception of the vastus internus and externus, both of which—especially the vastus internus—are definitely atrophic. Case 3 shows a similar atrophy of the vasti, but there is in addition a considerable weakness of all the muscles below the knees, especially of the dorsiflexors of the feet, associated, not with wasting, but with an apparent hypertrophy of the muscles. In Case 5 the thigh muscles have escaped atrophy, but here there is wasting and weakness of all muscles below the knee, especially of the dorsiflexors of the feet, which are completely paretic.

Case 3 cannot unreasonably be regarded as forming a link between Cases 1 and 4 on the one hand and Case 5 on the other, and the history which F. W. gives in the case of his dead brother suggests that in this instance also weakness of the dorsiflexors of the feet was a prominent feature.

The unusual and apparently irregular distribution of the wasting in cases of myotonia atrophica has been commented on by most observers. Hoffmann pointed out the almost constant involvement of the face, the frequent affection of the masseters and the escape of the intrinsic muscles of the hands, but he does not appear to have laid any considerable emphasis on this distribution, for he makes irregularity of distribution one of the points of his argument in favour of the condition being primarily one of myotonia. The cases which we have here recorded seem, however, so strongly to suggest that a characteristic distribution may exist in the disease, that we have investigated all the cases which have been recorded with a view to determining how closely they correspond to our own.

We have succeeded in discovering twenty-nine recorded cases. Three presented symptoms which suggested strongly some complicating lesion of the nervous system. Frohmann's case showed nystagmus and Rombergism, Lortat-Jacob and Thaon's an extensive anæsthesia, and Pelz's nystagmus and hyperalgesia of the nerve-trunks. Of the remaining twenty-seven cases, fifteen present a distribution approximating closely to that which we have here described. These fifteen cases, with our own five, seem to form so definite a group that we give a short abstract of their clinical features in an appendix. In the remaining twelve cases the atrophy differed so widely in distribution from our own that we have neglected them, for it is our object not so much to discuss the whole subject of myotonia atrophica, as to suggest the possibility of there existing a form of myopathy differentiated clinically from the classical types, as much by the distribution of the wasting as by the presence of the myotonia.

From an analysis of our own cases and those in the literature which most closely resemble the "type" described we are able to draw the following conclusions with regard to the leading features of the condition.

(1) *Familial Characters.*

In several of these cases the disease occurs in more than one member of a family. Hoffmann [8] recorded the disease in a brother and sister,

Pässler in two brothers, Ramsay Hunt in two brothers, and Batten and Gibb a family in which a brother and sister were certainly affected and probably a second brother who did not come under observation. Among the cases which we have here collected there was no instance of the presence of myotonia without atrophy in members of the same generation.

Direct heredity could not be traced in any case, but Rossolimo [17] records the case of a man whose father had (according to the son) presented symptoms of myotonia; and one of our patients states definitely that his mother suffered throughout her life from a difficulty in relaxing her grasp. In both these parents there was, so far as is known, no muscular wasting. In no instance was a history of myopathy in ascendants or the collaterals of ascendants obtained.

(2) *Etiology.*

The disease arises in most instances without apparent cause. In two cases reported by Hoffmann and Fürnrohr the condition was attributed to exposure to severe cold. In Rossolimo's case the condition followed an acute illness characterized by a painful swelling of the knee-joints, and in one of our own an attack of acute rheumatism closely preceded the first onset of the weakness.

Such apparent causes of origin, if they have any significance at all, can scarcely be regarded as other than secondary in determining the onset of the disease.

(3) *Sex.*

The disease is much commoner among males. Few as the recorded cases are, they can leave no doubt on this point. In only three out of twenty cases were the patients women—viz., in Hoffmann's, Batten and Gibb's [2], and Kleist's [10] cases—and it is interesting that in two of these the symptoms were slight and had escaped observation till the presence of the affection in a more marked degree in other members of the family had directed attention to the condition.

(4) *Age of Onset.*

The symptoms make their appearance in early adult life; in the majority of cases between the ages of 20 and 30. The earliest age at which symptoms have appeared is 15 (Kleist [10]). In a few instances the onset has been delayed till beyond the thirtieth year. The myotonia usually precedes the atrophy, but not invariably. In the two cases

recorded by Ramsay Hunt, muscular wasting had been noticed for many years before myotonic symptoms showed themselves, and in one of our own the myotonia did not appear till 1907, though the wasting had reached an advanced degree in 1906.

(5) *Distribution of the Atrophy.*

Atrophy of the facial musculature is almost constant (sixteen in twenty). In all our cases the features had the expressionless immobile character seen in the Landouzy-Dejerine type of myopathy, and the weakness of the facial muscles, especially of the orbicularis palpebrarum and the orbicularis oris, was manifest on all attempts at voluntary movement.

In half the cases (ten in twenty) the masseters and temporals were also affected. In one instance (Nonne [13]) the atrophy had reached so high a degree as to have caused a bilateral dislocation of the jaw.

The sterno-mastoids were also frequently affected (thirteen in twenty). In these thirteen cases the sterno-mastoids on both sides were atrophic; this atrophy contrasts forcibly with the almost constant escape of the trapezii, which were atrophic in three instances only. The other muscles of the neck have always escaped. The muscles of the shoulder and upper arm were rarely involved. In some few cases there has been noticed a wasting of the supraspinati and infraspinati; the deltoid was atrophied in a slight degree in one instance only; the other muscles about the shoulders have always escaped. The muscles of the upper arm were affected in four of these cases, but only to a slight degree. The biceps generally suffered most where the upper arm was affected. But the most constant feature in all these cases is the involvement of the forearm musculature. The atrophy did not involve any particular group of muscles, both flexors and extensors suffered, though, as a rule, the flexors were weaker and more wasted than the extensors.

In striking contrast to the wasted condition of the forearms is the non-atrophic state of the intrinsic muscles of the hand, which in most cases were preserved. In only four cases was there any atrophy of these muscles. It involved especially the thenar and hypothenar eminences.

The trunk muscles in all instances escaped, but the legs were almost invariably affected; of the thigh muscles, the extensors of the knee far the most commonly (nine in twenty). The adductors of the thigh were involved in one instance only, and the other muscles of the thigh invariably escaped. Where the atrophy invaded the quadriceps extensor

femoris it showed a tendency to affect the vastus internus and externus and leave the rectus femoris intact. This is strikingly shown in three of our cases.

But of the lower limb muscles, those below the knee were the most commonly affected, and of these the peronei and dorsiflexors of the foot more commonly than the calf muscles. Weakness of the dorsiflexors was present in ten of these nineteen cases, and in one instance (Lannois [11]) the forearms and dorsiflexors of the foot were alone involved. In nine out of twenty cases the calf muscles were weak, but as a rule the weakness was less marked than in the dorsiflexors and in no case were the calf muscles affected without involvement of the dorsiflexors.

In three instances the laryngeal muscles were affected. In Nonne's case there was "a paresis of the vocal cords"; in Siemerling's paralysis of the adductors (thyro-arytænoideus), and in one of our own the patient first sought advice for an abductor palsy of one of the cords.

(6) *The Myotonia.*

The myotonic phenomena are shown far more commonly in a difficulty in relaxing the grasp than in any other voluntary movement. In all cases this phenomenon has been present and in most instances has been the only voluntary movement showing the presence of myotonia. Even in cases in which the myotonia is not confined to this particular movement, it is far more conspicuous in it than in any other. Rossolimo's case, in which this disability involved to a considerable degree all movements of the upper arm and neck, is the only one recorded in which the myotonia was at all conspicuous in other parts of the body. In all other instances the myotonic phenomena were slight and most frequently apparent in the muscles supplied by the cranial nerve, the facial muscles, the muscles of mastication and the tongue. Myotonic phenomena are not common in lower limbs, and when present are always slight in degree.

Further, the myotonic appears to bear no relation to the atrophy, so far as voluntary movements are concerned. Even in instances in which the atrophy in the lower limbs is considerable, myotonic phenomena are generally absent.

Appendix.

Nonne [13].

Male, aged 40. Atrophy of facial muscles, masseters, neck (muscles not specified), shoulder-girdle, forearms, thighs and peronei. Paresis of vocal cords.

Myotonia in limbs and eyelids. Mechanical and electrical myotonia reaction in all muscles not atrophied and in some atrophic muscles.

Knee-jerks and ankle-jerks absent, and deep reflexes in arms diminished.

Pässler [15]. Two brothers.

Case 1.—Aged 35. Myotonia first noticed at puberty. Weakness and atrophy of hands some years later.

Atrophy of facial muscles, masseters, temporals, sterno-mastoids, supraspinati and infraspinati, flexors and extensors of forearms, intrinsic muscles of the thumb and of fourth interossei.

The legs are said to have been slightly weak, but there is no record of atrophy in the lower limbs.

Pronounced myotonia in hands and arms.

Case 2.—Aged 33. Myotonia first at 18. For the last few years wasting of hands.

Atrophy of facial muscles, masseters, temporals, sterno-mastoids, supraspinati, infraspinati, and of interossei muscles of the feet.

Hoffmann [8]. Brother and sister.

Case 1.—Male, aged 26. Has three living sisters; two of them seen by Hoffmann: one of these healthy, the other is the second case recorded.

Weakness of grip noticed at the age of 20, attributed to exposure to cold. Steadily increasing weakness and wasting of forearms. The weakness of the face probably present since the age of 18. Difficulty in speaking present for a year; no record of date of onset of myotonia in hands, but said to have been healthy as a child.

Atrophy of facial muscles, masseters, sterno-mastoids, flexors of left arm, muscles of forearm in both limbs more advanced in the flexors than the extensors. The lower limbs are unaffected.

Myotonia present in forearm and hand muscles, slighter in degree in tongue and upper arms. Deep and superficial reflexes all present. Myotonic, electrical and mechanical reactions in the muscles of the upper extremities, but not in those of the lower extremities.

Case 2.—Female (sister of above), aged 30. Considered herself healthy.

Atrophy of facial muscles, masseters, sterno-mastoids, and the muscles of the forearms, especially the flexors.

The lower limbs involved.

The hands show a typical myotonia, and the myotonic electrical reaction is present in the forearm muscles. Deep and superficial reflexes present.

Fürnrohr [6].

Case 1.—Male, aged 33. No history of a similar condition in family. When 20 years old noticed a difficulty in relaxing his grasp; twelve years later began to lose power in his legs.

Atrophy of the forearm and thigh muscles, the lower leg being well developed. The knee-jerks are absent. Myotonia in forearm muscles.

Case 2.—Male, aged 50. For some years slowly progressive muscular atrophy. Atrophy involving the facial muscles, flexors of the head, shoulder muscles, forearms and hands. Also weakness and atrophy of the thighs and legs. He complained of no myotonic symptoms, and it was only after careful examination that these were detected.

Rossolimo [17].

Male, aged 37. No history of similar condition in parents or other relatives. Always healthy till onset of present condition.

When 22 years old he began to show a progressive wasting and feebleness of the whole body; ten years later the right knee, without apparent cause, became red, swollen, and painful. The other joints were unaffected. Two months after this he noticed a progressive weakness about this knee, and shortly afterwards the left knee began to get weak too, and he frequently tripped and fell. He noticed, too, a stiffness about the knees when he first started walking, which passed off after a few steps. At the same time as the difficulty in walking commenced he began to have a stiffness about all movements of the upper limbs, which passed off after repeated movements. The power of the movements of the upper limbs began to fail at the same time.

Present condition.—Atrophy involving face masseters, forearms, extensors and adductors of thighs with symmetrical wasting of muscles below the knees.

The myotonia is shown principally in the flexors of the forearm, but is present in movements of the upper arm, neck, and lower limbs.

The knee-jerks are difficult to elicit, and the ankle-jerks are abolished.

Lannois [11].

Male, aged 37. No history of a similar condition in any relatives.

When 3 years old it was observed that he threw out his feet in walking. Two years later lightning pains in lower limbs; first myotonia noticed in movements of hand, three years after difficulty in walking began.

Present condition.—Atrophy. Forearms, not localized to any special group of muscles, dorsiflexors of feet, and to a less degree of calf muscles. Myotonia shown chiefly in forearm muscles, but to a lesser degree in movements of lower limbs, and in talking and chewing.

The deep reflexes are absent.

Noguès and Sirol [14].

Male, aged 33. His father had some difficulty in starting to chew. No other relatives affected.

When 17 years old noticed a difficulty to chew, and also a difficulty in relaxing his grasp. At the age of 28 he began to tire easily in walking, and noticed a stiffness about his legs on first starting to walk.

Present condition.—Slight general wasting and weakness of arms. Atrophy of inner belly of gastrocnemius in both legs and of the tibialis anticus and common extensor of the toes, and to a less degree of the peronei. Very obvious wasting of the vastus internus in both limbs.

The deep reflexes are diminished, but not abolished.

Schönborn.

Male, aged 22 (from Hoffmann). Always slower than other men, and his speech has always been nasal. For the last two years has had progressive weakness and wasting of muscles of hands and forearms.

Present condition.—Atrophy of hand and forearm muscles, and of the extensors of the lower limbs.

Siemerling [18].

Male, aged 31. When 26 years old wasting of forearms began. When 27 began to suffer from a feeling of stiffness in muscles as soon as he wished to perform a movement, passing off after repeated efforts.

Present condition.—Atrophy affecting face masseters, tongue, sterno-mastoids, trapezii, especially middle and lower part, supraspinati and infraspinati, deltoids, especially middle portion upper and lower arm. Thighs powerful, lower legs weak.

There is also weakness of the adductors of the vocal cords.

Knee-jerk absent in left leg; obtained only with reinforcement in the right one.

Ramsay Hunt [7].

Two brothers. Another brother, now dead, is said to have presented similar symptoms.

Case 1.—Aged 44. For ten years has had weakness of the hands, and for six years of the lower extremities. Three years ago myotonia phenomena first noticed.

Present condition.—Atrophy involving face, upper arm, forearms and muscles below the knees, especially the dorsiflexors. Myotonic phenomena in forearm muscles, to a less degree in the movements of the lower limbs.

The deep reflexors are abolished.

Case 2.—Aged 41. When 23 years old noticed weakness of the hands and arms. Not till the age of 33 did myotonic phenomena show themselves. Then they appeared in the movements of the hand, and about the same time stiffness and weakness of the lower limbs appeared.

Present condition.—Atrophy involving face, upper arms, forearms, and muscles below the knee, especially the dorsiflexors.

Myotonic phenomena only in movements of hands.

Deep reflexes greatly diminished.

Kleist [10] has described a case under the title, "Nachdauernde Muskelkontraktionen" of a woman aged 29.

She was well till 7 years old, when she had gastric fever, followed by chorea, and when about 15 years old she had some unsteadiness of the right hand.

About this time she noticed that the hand "stood still," and that when she grasped an object she could not let go. The patient continued at work till she was 26. The increasing weakness made her give up her work.

On examination, a lingering contraction of the flexor muscles of the hand was observed. The more powerful the contraction the longer is the period of relaxation, but repetition of the movement does not diminish the tendency to this lingering contraction. The same phenomenon is found in some other muscles of the body.

The muscles are readily exhausted on voluntary movement, but there is no myasthenic reaction to electrical stimulation.

There is atrophy in the dorsal forearm muscles and the dorsiflexors of the feet, of the sterno-mastoids and of the facial muscles. Scoliosis, pes equinus, and claw-foot were also present.

There was slight sensory disturbance on the outside of the thighs.

The author argues at some length that the myotonic condition of the muscles is due to affection of the fronto-pontine-cerebellar tract.

The case is one which does not correspond in a good many points with the cases we have described. It is especially noticeable that the lingering contraction of the muscles is not removed in this case by repeated movements, as it was in other cases.

References.

[1] Batten. "Case of Myopathy, exhibiting Slow Relaxation of Muscles after Muscular Action," *Brain*, 1906, vol. xxix, p. 414.

[2] Batten and Gibb. "Two Cases of Myotonia Atrophica, showing a Peculiar Distribution of Muscular Atrophy," *Proc. Roy. Med. Soc.*, 1908, Neurological Section, p. 32.

[3] Buzzard. "An Unusual Case of Muscular Atrophy," *Proc. Roy. Soc. Med.*, 1908, Neurological Section, p. 33.

[4] Fox. "A Case of Laryngeal Paralysis," *Proc. Roy. Soc. Med.*, Laryngological Section, 1908, p. 107.

[5] Frohmann. "Ueber Thomsensche Krankheit mit Muskelatrophie," *Deut. med. Woch.*, 1900, V.B., S. 6.

[6] Fürnrohr. "Myotonia Atrophica," *Deut. Zeit. f. Nervenh.*, 1907, xxxiii, S. 25.

[7] Hunt. "Myotonia Atrophica," *Journ. Nerv. and Ment. Dis.*, 1908, xxxv, p. 269.

[8] Hoffmann. "Ueber Myotonie," *Neurol. Centralb.*, 1905, S. 576.

[9] *Idem.* "Zur Lehre von der Thomsenschen Krankheit mit besonderer Berücksichtigung des dabie vorkommenden Muskelschwundes," *Deut. Zeit. f. Nervenh.*, 1900, xviii, S. 198.

[10] Kleist. "Ueber Nachdauernde Muskelkontraktionen," *Journ. f. Psych. u. Neurol.*, 1907, x., S. 95.

[11] Lannois. "Myotonie avec atrophie musculaire," *Nouv. Iconogr. de la Salp.*, 1904, p. 450.

[12] Lortat-Jacob et Thaon. "Atrophie musculaire avec réactions electriques de la maladie de Thomsen," *Arch. de Neurol.*, 1905, xx, p. 132.

[13] Nonne. "Combination von Myotonie und Dystrophia Muscularis," *Neurol. Centralb.*, 1905, S. 142.

[14] Noguès et Sirol. "Maladie de Thomsen à forme fruste avec atrophie musculaire," *Nouv. Iconogr. de la Salp.*, 1899, xii, p. 15.
[15] Pässler. "Zwei Brüder mit Amyotrophischer Myotonie," *Neurol. Centralb.*, 1906, S. 1064.
[16] Pelz. "Ueber Atypische Formen der Thomsenchen Krankheit," *Arch. f. Psych. u. Nervenkrank.*, 1907, xlii, S. 704.
[17] Rossolimo. "De la myotonie atrophique," *Nouv. Iconogr. de la Salp.*, 1902, p. 63.
[18] Siemerling. "Fall von Myotonia congenita, Muskelatrophie und Myasthenia," *Münch. med. Woch.*, 1905, lii., S. 1072.

NOTE ON THE MOVEMENTS OF THE TONGUE FROM STIMULATION OF THE TWELFTH NUCLEUS, ROOT, AND NERVE.

BY AUBREY T. MUSSEN, M.D.

McGill University, Montreal.

DURING the winter of 1907-8 it was my privilege to be associated with Sir V. Horsley in an investigation into the functions of the inferior olive.

To reach this important group of cells it was necessary for the stimulating needle to pass through the fibres of the twelfth root, and we frequently observed that while stimulation of some of these fibres caused the tongue to protrude to the right, stimulation of other fibres of the same root produced a strong protrusion of the tongue to the left.

In the course of my investigations, which have been continued at McGill during the past year, I have always been puzzled by this protrusion of the tongue to the *left* on stimulating the left twelfth root, for it is generally understood when the tongue is protruded from the left side of the mouth, or into the left cheek, that this movement is due principally to the protruding action of the right half of the tongue assisted by the contraction of the left half [1].

The purpose of this paper is to show that the protrusion of the tongue from the left side of the mouth, and the protrusion of the tongue into the left cheek, may be accomplished by the muscles of the left half of the tongue alone without any assistance from the right half.

In these experiments Dr. Clarke's stereotaxic instrument [3] has been employed. The animal was deeply anæsthetized and the instrument adjusted. The medulla was exposed from the foramen magnum to a few millimetres below the superior border of the atlas so as to have free access for the needle to the twelfth nucleus and root. The movements of the tongue were observed on stimulating (1) the twelfth nucleus, (2) the root in its course through the medulla, and (3) the twelfth nerve in the neck.

On stimulating the left twelfth nucleus (*mutatis mutandis* the same is true of stimulation of the right nucleus), the following movements were observed:—

The tongue was protruded to the opposite side (right); the tongue was curled upwards and over to the right canine tooth. But the most unexpected reaction was a strong protrusion of the tongue from the mouth on the left side.

When the left twelfth root in the medulla was stimulated, similar movements were produced. The tongue was curled upwards and to the right or opposite canine tooth, while stimulation of other fibres caused the tongue to protrude from the angle of the mouth *on the same (left) side.*

The most frequent reaction on stimulating the (left) twelfth nerve in the neck was *a strong protrusion of the tongue out of the mouth on the same side.* Other reactions were: protrusion with the tip of the tongue strongly to the right or opposite side, and curling up of the tip, now to the right and at other times to the left.

Effects after Median Sagittal Section of the Tongue.

To exclude any assistance from the right half of the tongue in these movements, the tongue was then divided into two halves along the raphé and the same parts were again stimulated in the nucleus, root, and nerve.

On *stimulating the left nucleus*, the *left half* was protruded to the *right*; the left half could curl up and over to the right canine with no movement of the right half. On reaching the spot that caused on stimulation a strong protrusion of the tongue to the left, *i.e.*, to the same side, it was interesting to see how this movement was produced, for the left half was retracted in a straight line and the right half was strongly protruded—showing the close association of the two nuclei.

This conjugate action of the two separated halves of the tongue was first described by Beevor and Horsley [2] on stimulating the upper part of the tongue area in the right hemisphere.

Stimulation of the left twelfth root caused the left half to curl up to the opposite (right) canine; stimulation of other fibres produced a strong protrusion of the left half to the right; and on stimulation of this left root in another area, the left half was protruded from the left angle of the mouth while the right half remained motionless.

When the *nerve* was stimulated the movements of the left half of the tongue were the same as those observed before the tongue was divided, but now were performed by the left half only.

It will be noticed that when the tongue was protruded from the left

side on stimulating the *left nucleus*, that this movement was due to the retraction of the left half and the protrusion of the right. But when the *root* or the *nerve* was stimulated the protrusion from the left side was accomplished by the muscles of the left half alone.

Having demonstrated the actions of the tongue in the cat, and feeling that a carnivorous animal was probably not suitable for comparison with man, I concluded this investigation by repeating these experiments on a bonnet monkey.

The twelfth nucleus, root, and nerve were stimulated, first with the tongue in a normal state, and then after dividing it into two halves.

All the movements corresponded with those found in the cat and may be summarized as follows :—

(1) The half of the tongue that is stimulated can be protruded to the opposite side as far as the canine teeth.

(2) Can be protruded straight.

(3) Can be protruded from the same side.

(4) Can be protruded into the cheek of the same side.

(5) The tip of the tongue can touch the teeth and gums of the upper and lower jaw on the same side, and as far as the canine teeth, upper and lower, on the opposite side.

(6) The tip of the tongue can curl upwards and backwards to the roof of the mouth on the same side.

In fact, it was clearly demonstrated that the only movements that the stimulated half of the tongue could *not* perform were : protrusion from the opposite angle of the mouth, protrusion into the opposite cheek, as well as the inability to touch the molar teeth and the gums on the opposite side.

Therefore, these experiments show that when one half of the tongue is paralysed from affection of nucleus, root, or nerve, the following symptoms are observed :—

Inability to touch the teeth, the gums, or to protrude the tongue into the cheek of the paralysed side, while there is perfect freedom of movement to the sound side, the tongue being easily protruded into the cheek of this side and the teeth and gums being readily touched ; in advanced cases secondary atrophic changes in the paralysed half may, however, greatly interfere with the movements of the sound half.

References.

[1] Beevor. *Brain*, 1906, p. 487.
[2] Beevor and Horsley. *Phil. Trans. Royal Society*, 1894, vol. 185, p. 56.
[3] Horsley and Clarke. *Brain*, 1908, vol. xxxi., p. 1.

THE OCCURRENCE OF REMISSIONS AND RECOVERY IN TUBERCULOUS MENINGITIS: A CRITICAL REVIEW.[1]

BY ALFRED E. MARTIN, M.D.

I. Introduction.

The majority of the medical profession have found the termination of tuberculous meningitis so uniformly fatal that the greatest scepticism has been shown with regard to the diagnosis of cases in which there were prolonged remissions of symptoms or in which recovery occurred.

Taylor [55], for instance, writes: "Undoubtedly tubercular meningitis is in nearly all cases fatal; and the prognosis may be regarded as unfavourable in proportion to the certainty of the case being tubercular." According to Gowers [25], "doubt always hangs over the exact nature of the cases that recover, but the probable evidence as to the tubercular character of some of these cases is very strong." And in the opinion of Barlow [3], "the study of the morbid anatomy of the disease gives us the only reasonable basis on which to discuss the subject of prognosis. If the tuberculous deposition be limited to a part of the surface of the brain, there is a possibility of recovery; but if the disease becomes generalized, so that besides the invasion of the pia mater there is an extensive meningo-encephalitis with or without hydrocephalus, the chance of recovery is practically *nil*." Within the last ten years, however, methods have been more generally employed by means of which the diagnosis of tuberculous meningitis can be confirmed during life, and it is now possible to prove beyond doubt that a patient is suffering from tuberculous meningitis while he is yet alive.

The object of this paper is to sift the evidence obtainable and to show that tuberculous meningitis does sometimes recover, or that long remissions may occur during its course.

It is instructive, in the first place, to examine the statistics of institutions in which large numbers of cases of tuberculous meningitis are observed. I have therefore analysed the reports of several London

[1] This paper was part of a thesis presented for the degree of M.D. to the University of Cambridge.

hospitals, and the reports of the Vienna hospitals[1] since the year 1897. In the clinical reports of seven London hospitals issued since that year 797 cases of tuberculous meningitis are referred to, and of these 16, or approximately 2 per cent., recovered; while in the Vienna hospitals during the same period there were 1,369 cases, but of these only six, or 0·44 per cent., are reported as recoveries. Thus, of 2,166 cases diagnosed as tuberculous meningitis twenty-two only, or about 1 per cent., were discharged from hospital cured or relieved.

These figures cannot, however, be accepted without criticism, and there is no doubt that the percentage of recoveries shown in the figures taken from the records of the London hospitals is too high. I have personally examined the notes of thirteen out of the sixteen cases recorded as recoveries in the seven hospitals from the reports of which these figures were obtained, and have found that one case had been recorded as a recovery through a clerical error; two cases had been in hospital for so short a period—two days and fourteen days respectively—that they cannot be accepted as cases of tuberculous meningitis; two other cases were removed from hospital while acute symptoms were still present, so that they cannot be considered recoveries; and two were discharged unimproved. The notes in one case were missing. In four of the remaining five cases examined, the diagnosis was made on clinical evidence only; in the other there was, in addition to clinical evidence, an increase in the cell elements in the cerebrospinal fluid (polymorphonuclear cells being in excess of lymphocytes), while on two occasions the fluid proved sterile after incubation for three days; this excludes meningococcal and suppurative meningitis.

As a result of this investigation the number of *possible* recoveries reported in the statistics of the seven London hospitals given above *must* be reduced to nine.

I was, unhappily, unable to trace the records of four of these cases; in four of the remaining five cases the diagnosis was made on clinical grounds alone, and consequently they cannot be accepted for the purpose of statistics. The remaining case, in which the clinical diagnosis was supported by the existence of an increase in cell elements in the cerebrospinal fluid that remained sterile on incubation, is the only one in which there was a strong probability of tuberculous meningitis.

In any research on the subject it is essential that the nature of all the cases in which a prolonged remission or recovery is recorded should be placed beyond doubt.

[1] *Jahrb. der Wiener Krankenanstalten.*

The diagnosis of this disease by clinical methods alone often presents the greatest difficulty, as there is no pathognomonic symptom. It is increased by the fact that the initial symptoms of infectious diseases, especially of enteric fever, pneumonia, and broncho-pneumonia, in children often resemble those of tuberculous meningitis, and in young children teething and gastric disturbances give rise to somewhat similar symptoms. Finally, other forms of infective meningitis and the meningeal symptoms in uræmia, lead poisoning, and hysterical pseudo-meningitis may also lead to confusion.

Hence it is impossible to accept a diagnosis of tuberculous meningitis as certain if it is based solely on the clinical symptoms, though the probability may be very great.

II. Methods of Confirming the Diagnosis.

To establish the diagnosis of tuberculous meningitis further steps are necessary; of these the chief is lumbar puncture. By this means we are able to obtain information as to—

(1) The tension of the cerebrospinal fluid.

(2) The appearance and chemical nature of the fluid.

(3) The presence or absence of tubercle bacilli or other organisms in the fluid by microscopical examination.

(4) The presence of tubercle bacilli in the fluid by the experimental production of tuberculosis by inoculation of a susceptible animal like the guinea-pig.

(5) The presence of tubercle bacilli by their cultivation in special media.

(6) The presence or absence of an excess of cell elements in the fluid, and the nature of the cells which are present.

These different points may be considered in this order. Usually the cerebrospinal fluid escapes from the needle drop by drop, but in tuberculous meningitis the tension is generally increased and the fluid jets out in a continuous stream. In health it is a transparent, colourless, watery fluid, and, though it often retains this character in tuberculous meningitis, it may be greenish-yellow in colour or, in the last stage of the disease, even opaque. It thus differs from the fluid in cases of meningococcal, streptococcal, and pneumococcal disease, as in these conditions it is usually turbid or even purulent, though in chronic cases of meningococcal meningitis which recovered or became hydrocephalic Forbes [20] found that the cerebrospinal fluid was clear. On standing, a fibrinous clot

frequently separates out, which is finer than the clot that appears in meningococcal or purulent meningitis.

The presence or absence of a reducing body in the fluid may give information of some value. Bernstein [5] found that Fehling's solution was reduced in twelve of fifty-three cases of tuberculous meningitis, even though the fluid was obtained only a few days before death; but that in cases of purulent meningitis the reducing body was invariably absent.

According to Forbes [21], who examined the cerebrospinal fluid from twenty-five cases of tuberculous meningitis, the reduction took place readily in nine, slightly in nine others, while in six it was absent.

On the other hand, in fifteen specimens of fluid from cases of meningococcal meningitis he found that two obtained in the acute stage readily reduced Fehling's solution, while six at a later stage of the disease only gave a partial reduction, and seven obtained during a chronic stage gave no reduction at all.

Formerly it was considered that the presence of sugar in a cerebrospinal fluid was sufficient in itself to exclude the diagnosis of an advanced tuberculous meningitis, but these observations prove that this is not the case. Bernstein suggests that the mistake arose through an insufficient quantity of cerebrospinal fluid being used, as ten cubic centimetres at least are required for the test.

The presence of tubercle bacilli may be detected by the microscope in one of two ways:—

(*a*) Where a clot is formed in the fluid the bacilli may be frequently found without difficulty by teasing it out on a slide and staining by the usual Ziehl-Nielsen method. In this way out of fifty-four specimens Forbes found bacilli in forty-three—*i.e.*, nearly 80 per cent.—while Bernstein found them in 100 out of 102 specimens examined; in some of the cases, however, the latter observer found it necessary to search for several hours before obtaining a successful result.

(*b*) By the examination of the centrifugalized cell deposit. This method is very tedious, as it requires a prolonged centrifugalization of the fluid and a search of several hours.

In cases where tubercle bacilli are not found by the methods just mentioned, proof of the tuberculous nature of the case may be obtained by the subcutaneous or intraperitoneal inoculation of guinea-pigs. This method, according to Bernstein, is absolutely trustworthy; on the other hand, Madame Hirschorn found that in patients suffering from non-

tuberculous meningitis, or from tubercle elsewhere than in the meninges, inoculation with the cerebrospinal fluid did not infect guinea-pigs.

The presence of tubercle bacilli may be also demonstrated by the inoculation of broth, glycerin-agar or potato-tubes, on which the bacillus grows fairly readily. This method, however, frequently fails, and a negative result is of no great importance.

When lumbar puncture was first commonly practised it was found that in tuberculous meningitis the bulk of the cells were lymphocytes, whereas in suppurative meningitis polymorphonuclear cells were markedly in excess. On the other hand, the cerebrospinal fluid of those patients who, without actual disease of the meninges, presented the appearance of meningitis showed no increase of cell elements. From these facts it was hoped that a means had been discovered by which a definite diagnosis of meningitis and its nature could be made, but this unfortunately has been proved false by more recent investigations.

Rossi [48] states that the relationship between lymphocytosis and tuberculous meningitis is not constant, and that errors in diagnosis will occur if a pathognomonic value is attached to the presence of a lymphocytosis in the differential diagnosis of acute meningitis.

A constant predominance of mononuclear small cells was found by Goggia [24] in a case of meningococcal meningitis which terminated fatally.

Mutzner [40], again, concluded from the study of a series of cases confirmed by *post-mortem* examination—

(*a*) That in the cerebrospinal fluid of patients who are not suffering from tuberculous meningitis the cell elements present may be chiefly mononuclear, and (*b*) that there are cases of tuberculous meningitis in which an excess of polymorphonuclear cells occurs.

Porot's [43] results indicate that cyto-diagnosis is of little value, as in some cases all cellular reaction is absent, while in others the percentage of polymorphonuclear cells is very high.

Forbes [21], who has examined eighty cases of tuberculous meningitis, of which seventy were verified either by *post-mortem* examination or by the discovery of tubercle bacilli in the cerebrospinal fluid during life, found an excess of lymphocytes in fifty-one, an excess of polymorphonuclear cells in five, while in four cases the proportions of the cells were about equal. He considers from clinical and *post-mortem* evidence that the predominance of polymorphonuclear cells is associated with a chronic meningitis which terminates acutely, and in which several tuberculous nodules, in addition to a large amount of plastic lymph, are

present. In cases of tuberculous tumours of the cerebrum and cerebellum without any accompanying meningitis, the same observer found that the cerebrospinal fluid was practically normal.

In 102 examinations of the cerebrospinal fluid made by Bernstein [5] only three exceptions were found to the mononuclear lymphocytosis usually present.

In this connection it is important to remember that a lymphocytosis is constantly or almost constantly present in the cerebrospinal fluids of patients suffering from para-syphilitic conditions, such as tabes dorsalis and general paralysis of the insane, and that this also occurs in some cases of general syphilitic disease of the central nervous system.

From these facts it is evident that a lymphocytosis in the cerebrospinal fluid of a case with the clinical symptoms of meningitis adds to the probability of its being tuberculous, but that a positive diagnosis cannot be made on these grounds alone.

To sum up briefly the results that may be obtained from the examination of the cerebrospinal fluid, we find that although the character, chemical constitution, and cytological contents are of considerable aid to the diagnosis of tuberculous meningitis, yet it can be only affirmed with certainty that a case of meningitis is tuberculous when one of the following conditions has been fulfilled :—

(1) When tubercle bacilli are discovered in the cerebrospinal fluid by the microscope, inoculation, or culture ;

(2) When tubercle bacilli have been cultivated from the fluid ;

(3) When inoculation of a guinea-pig has given a positive result.

Ophthalmoscopic examination of the fundus of the eye may sometimes afford valuable assistance, as in some cases of tuberculous meningitis tubercle of the choroid is present. Opinions differ widely as to the frequency with which this condition occurs in tuberculous meningitis. Treacher Collins [14] states that Bouchet found tubercle of the choroid in 10 per cent., Carpenter and Stephenson in 50 per cent. of unselected cases ; while in contrast to these figures Jessop [34], who examined a large number of cases, found it present in approximately only 2 per cent. to 5 per cent., and then as a rule only shortly before death.

Accurate ophthalmoscopic examination of a patient suffering from meningitis is not easy, and errors in observation may occur, as syphilitic disease of the choroid sometimes presents an appearance closely resembling miliary tubercle, while plastic cyclitis with detachment of the retina may be mistaken for a conglomerate mass of tubercle.

In addition to these methods, one of the tuberculin reactions, or the estimation of the opsonic index of the blood, may be employed to confirm or refute the clinical diagnosis.

Finally, in cases in which a patient has died after a long remission of symptoms, or from another disease after recovery from the meningeal symptoms, the *post-mortem* examination may prove that the diagnosis of the tuberculous nature of the meningitis was correct.

The above methods of diagnosis may be summed up under two main headings:—

(*a*) Those which point to a meningitis as being of a tuberculous nature: (1) the clinical evidence; (2) the differential count of the cells in the cerebrospinal fluid obtained by lumbar puncture; (3) the presence of tubercle in the choroid on ophthalmoscopic examination; (4) tuberculin reactions.

(*b*) Those which definitely prove the tuberculous nature of the meningitis—namely: (1) The demonstration of tubercle bacilli in the cerebrospinal fluid by the microscope, by inoculation experiments, or by cultivation in artificial media; (2) *post-mortem* examination after remission or recovery.

III. A Critical Review of the Literature.

While the records of the London hospitals to which I have had access have failed to give me any cases of recovery from tuberculous meningitis in which the diagnosis was established beyond doubt, a search through the literature on the subject has afforded much evidence that patients with tuberculous meningitis may and actually do recover, and that in other cases remissions of the acute symptoms for several months may occur during the course of the disease.

The cases which I have collected from the literature on this subject may be conveniently divided into (1) those in which a long remission of the symptoms occurred, and (2) those which terminated in recovery. Each of these classes can be again subdivided into cases in which the tuberculous nature of the meningitis was proved definitely, and those in which there can be little doubt as to its tuberculous nature.

As in many of the cases that are classed under remissions the patients remained free from symptoms of active disease for months, it is evident that from the point of view of the subject of this paper there is no essential difference between these cases and those in which the recovery was permanent.

(1) *Remissions.*

(*a*) *Doubtful Cases.*—Don [16] records a case under the heading of "A Case of Tuberculous Meningitis in a Boy treated with Tuberculin. Recovery. Recurrence. Death." The diagnosis was made solely on clinical grounds, but the fact that after each injection of tuberculin the boy became worse for three days and then improved is mentioned as a confirmation of the diagnosis. The remission of symptoms was not for a prolonged period and no *post-mortem* examination was obtained, so that the diagnosis is uncertain.

Hahn [27] reported a case in which the clinical symptoms were those of tuberculous meningitis, and in which there was a remission of the acute symptoms for three years. No *post-mortem* examination was made. The only further evidence produced as to the nature of the disease was the fact that there was a tuberculous family history. Consequently the proof cannot be considered conclusive.

Dudon [17] reported a case to which Carrière and Lhôte [11] refer. In a boy of 17 an attack, in which for three weeks symptoms of meningitis were present, abated sufficiently for the boy to return to work. But an alteration in the lad's character was noted, and he suffered from tinnitus and occipital headache. A second and similar attack occurred three and a half years later, leaving severe pains in the head after recovery. The boy then became a drunkard, and died after six months in a final attack with symptoms of meningeal inflammation. No *post-mortem* examination was made. The criticism passed on the case when it was first reported was that the first attack was possibly one of enteric fever, and that the change of character which followed it was due to alcoholic excess. There is certainly no proof in this case of the nature of the meningitis.

Coulon [13] and Sepet [52] each observed a case in which the family history was very bad, the parents and other near relations being tuberculous, while the patients themselves suffered from tuberculosis. In Coulon's case death resulted from an acute miliary tuberculosis which had been preceded by two remissions of meningeal symptoms at intervals of twelve months and of four and a half years respectively. In Sepet's case the remission lasted a year. The presence of tuberculous lesions in other organs, with a history of tuberculosis in near relations, points to the probability of the meningitis in these cases being tuberculous, but it does not prove definitely that such was the case.

(*b*) *Certain Remissions.*—In the following cases of remission there can be no doubt as to the nature of the case.

Carrière and Lhôte [11] report four cases which came under their own observation and review the cases which had been previously recorded.

In their first case a boy, aged 5 years, was observed with Jacksonian epilepsy that began in the left side of the body and rapidly became general. Lumbar puncture showed a marked lymphocytosis in the cerebrospinal fluid; this demonstrated the presence of meningitis, as in cases of tuberculous tumours of the brain the cerebrospinal fluid obtained by lumbar puncture presents the features of healthy cerebrospinal fluid with but a very slight cell deposit. The tuberculous nature of the case was proved by the inoculation of a guinea-pig with a positive result. After four months, during which he suffered from two attacks of Jacksonian epilepsy and vomiting, the lad was able to leave the hospital. But nine and a half months later he was readmitted with symptoms similar to those of his previous attacks.

The lack of a *post-mortem* examination prevented the most satisfactory proof of the condition of the brain and meninges, but the positive result of the inoculation of the guinea-pig, together with the examination of the cerebrospinal fluid, enables us to consider the first attack of Jacksonian epilepsy as due to a tuberculous lesion in the cerebral cortex, with a meningitis that became latent for a period of some ten months.

The second case was that of a boy, 7 years old, in whose family there was a history of tuberculosis, while he himself had tuberculous enlargement of the cervical glands, one of which had broken down and formed a cold abscess. There was the clinical picture of tuberculous meningitis, and the diagnosis was confirmed by definite lymphocytosis of the cerebrospinal fluid, and by the death of a guinea-pig from tuberculosis after inoculation with 20 c.c. of the cerebrospinal fluid.

Improvement began ten days after admission, and at the end of two months the only physical signs remaining were slight strabismus and slight nystagmus when the eyes were in the extreme lateral position, together with a sluggish reaction of the pupils to light.

After an interval of four months a recurrence took place and the patient died. No *post-mortem* examination was made.

Their third case was that of a boy, aged 6½, whose mother was tuberculous; two brothers had died from meningitis and a sister was scrofulous. He himself had had a suppurating cervical gland when four years old.

For the first few days the diagnosis was doubtful, but later definite symptoms of meningitis appeared, and an examination of the cerebro-

spinal fluid showed a definite lymphocytosis. Moreover, a guinea-pig was inoculated and died of general peritoneal tuberculosis.

The discovery of tubercle bacilli in the cerebrospinal fluid, obtained by lumbar puncture at a later date, further confirmed the diagnosis; but, instead of death terminating the illness, the boy improved and gradually returned to almost perfect health: constipation, slight facial paralysis on the right side, and rapidity in respiration were the only physical signs remaining two months after the onset of the disease. The boy remained well until nine months later, when death occurred in a recurrence of the symptoms. A *post-mortem* examination was not allowed.

The last case reported by these authors was that of a boy, aged 4, in whom the clinical symptoms, the presence of a definite lymphocytosis in the cerebrospinal fluid, and the death of a guinea-pig from tuberculosis after inoculation with the fluid, made the diagnosis of tuberculous meningitis certain. A discrete tubercle of the choroid was also discovered in one eye on ophthalmoscopic examination. Improvement began on the eighth day after admission and continued until the child was discharged two months later. He was then irritable, constipated, and suffered from slight twitchings of the eyelids from time to time. There was also some weakness with slight tremor of the right arm. The respirations in this case also were rapid, being thirty in the minute. Ophthalmoscopic examination two months after his discharge from hospital showed that the tubercle of the choroid had vanished, but that there was now a diffuse irido-choroiditis, with slight œdema of the optic discs.

Four months after being discharged from hospital the child was readmitted with a recurrence of similar symptoms, and death rapidly ensued. On *post-mortem* examination definite signs of old meningitis were found; there was a dense sclerosis of the meninges over the fissure of Rolando on the left side, with general disseminated tuberculosis. Carrière and Lhôte [11] concluded from the *post-mortem* examination that there was a plaque of old sclerosed tuberculous meningitis over the left Rolandic fissure, with a recent miliary tuberculosis around it.

A case published by Rilliet [46] in 1853, and referred to by Carrière and Lhôte in their paper, is well worthy of comparison with the case just mentioned.

A boy, aged 5½, presented the clinical symptoms of tuberculous meningitis, but, instead of dying, he began to improve after fourteen days, and eventually recovered. Some time later he fell from a height and sus-

tained a fracture of the base of his skull, from which he recovered and was able to run about; no trace of either the illness or the accident remained, and for five and half years the child continued in excellent health, with such perfect intellectual development that he was able to keep the accounts of his father, who was an innkeeper. At the end of that time a recurrence of his former illness took place, and he died in ten days. *Post-mortem* examination revealed a mass of old meningitis over the middle and outer lobes of the left hemisphere of the brain, while a recent disseminated tuberculosis, of the type usual in tuberculous meningitis, was present in the meninges, especially at the base of the brain. The site of the old meningitis was very similar to that found by Carrière and Lhôte in the only case in which they were able to make a *post-mortem* examination.

The following case is of much interest. In October, 1900, a child, aged 8, was admitted under Rocaz [47] into the Children's Hospital, Bordeaux, with the characteristic clinical symptoms of tuberculous meningitis.

The lymphocytosis observed on examination of the cerebrospinal fluid, together with a history of tuberculosis in the parents and signs of phthisis in the patient, added to the probability that the meningitis was tuberculous. The child, however, recovered, the lymphocytosis disappeared, and, as at the end of nine months no signs of ill-health were detected, Rocaz published the case as an apparent recovery after an attack of tuberculous meningitis.

The sequel was published by Renée Cruchet [15], under whom the child was readmitted twenty-two months later with symptoms similar to those of the first attack, with, in addition, a marked deviation of the tongue to the right. Two months after readmission the child had improved to such an extent that he was up, playing with the other convalescents in the ward; but on this occasion the recovery did not last any length of time, and death followed a recrudescence of the disease. *Post-mortem* examination removed all doubts of the correctness of the diagnosis, as a thick mass of old tuberculous meningitis was found in the region of the pons Varolii, while recent miliary tubercles studded the meninges at the base of the brain.

Mermann [38] also published a case of remission of the symptoms for four months in a child who died during the second attack. *Post-mortem* examination showed that the meninges at the base of the brain were matted together by an exudation which extended into the Sylvian fissure, and in which, on microscopical examination, typical perivascular miliary tubercles were found.

(2) *Recoveries.*

(*a*) *Doubtful Cases.*—Buchanan [8] showed a child before the Liverpool Medical Institute who had had the clinical symptoms of tuberculous meningitis, in whom Calmette's ophthalmo-reaction gave a positive result, while there was a lymphocytosis of the cerebrospinal fluid withdrawn by lumbar puncture. Improvement followed an inoculation with $\frac{1}{4000}$ mg. of new tuberculin; this inoculation was repeated three weeks later, and uninterrupted recovery ensued. In this case the positive result of Calmette's ophthalmo-reaction shows the probable presence of tubercle somewhere in the body, while the lymphocytosis found in the cerebrospinal fluid is greatly in favour of the tuberculous nature of the meningitis; but on these facts alone the definite assertion that the meningitis was tuberculous cannot be made.

Jirasek [35] has reported a case in which the family history was very bad, the parents and other near relations being tuberculous, while the patient herself had pulmonary tuberculosis. Recovery took place after two attacks of meningeal symptoms with a year's interval between them.

Ovazza [42] and Porot [43] each record a case of recovery which clinically presented the typical appearance of tuberculous meningitis, but no further confirmation is given as to the nature of the disease. An interesting fact is recorded by Porot [43]: it is that there had been an attack of meningitis previous to the one he himself observed, which had left nystagmus, strabismus, and a facial tic. In this case the patient had an extremely bad family history as regards tubercle.

In the case recorded by Troisier and Broulé [59] the clinical symptoms of tuberculous meningitis were accompanied by a marked lymphocytosis in the cerebrospinal fluid, but no pathogenic organisms could be discovered. The meningeal symptoms lasted only eight days, and recovery was perfect, no sequelæ remaining after the meningeal symptoms had disappeared. Even the lymphocytosis was no longer present in the fluid obtained by a lumbar puncture done during convalescence. These authors regarded the presence of a lymphocytosis as conclusive evidence of the tuberculous nature of the meningitis, but it must be remembered that Goggia [24] found a constant predominance of lymphocytes in the cerebrospinal fluid in a fatal case of meningococcal meningitis during the course of the disease.

In cases reported by Sepet [52] and by Firmin Carles [9] it is recorded in confirmation of the clinical diagnosis that tuberculosis existed in near relations, that the progress of the disease was similar to

that of tuberculous meningitis, and that positive results were obtained, in Sepet's case with the sero-reaction of Arloing and Commont, in Carles' with Calmette's ophthalmo-reaction. The examination of the cerebrospinal fluid also revealed a lymphocytosis, which was considered to be definite proof of the tuberculous nature of the disease. The positive results of the tuberculin tests may have been due to tuberculosis in other parts of the body—for example, the mesenteric or posterior mediastinal glands. Further, in Carles' case measles, followed by whooping-cough and broncho-pneumonia, occurred during the presence of the meningeal symptoms, and, even though the measles did not appear until a month after the onset of the illness, the fact that meningeal symptoms often usher in an infectious disease must not be forgotten. The case must be consequently received with caution.

Sænger [51] has stated that five cases in which he made the diagnosis of tuberculous meningitis had recovered when treated with mercurial inunction, and that in three of them the recovery remained permanent; but he admitted that, as tubercle bacilli had not been demonstrated in the cerebrospinal fluid, the diagnosis was uncertain. He argued that the slow onset, the photophobia, and the general condition of the patients greatly favoured the diagnosis of tuberculous rather than of acute cerebrospinal meningitis.

Tripier [58] in 1902 also recorded eight cases of tuberculous meningitis which he had cured in the prodromal stage by repeated blistering of the head. As, however, he stated in this paper, that the treatment to be successful must be applied as soon as meningitis is suspected, and that it is too late if the least trace of contracture or of paralysis has appeared, his cases probably were not tuberculous meningitis.

Raw [44], again, in a lecture delivered at the Medical Graduates' College and Polyclinic, said: "In two cases of apparent tuberculous meningitis, with all the classical signs, the symptoms entirely disappeared after four injections of tuberculin, and both children made rapid recovery. In other two instances tuberculin had no effect, and the children died. Of course, it is impossible to be sure that the first two cases were of a tuberculous nature, as tubercle bacilli could not be recovered by lumbar puncture, but I have no doubt myself that they were."

(*b*) *Undoubted Cases.*—In the following cases, on the other hand, the correctness of the diagnosis is, I think, indisputable.

Freyhan [22], who was the first to publish a case in which the diagnosis was confirmed during life by the demonstration of tubercle bacilli in the cerebrospinal fluid, recorded the case of a workman, aged 20,

who was admitted to hospital, having suffered for three days with very severe headache in the occipital region, pains in the legs, and insomnia.

Examination revealed the characteristic symptoms of meningitis, which rapidly proceeded to the stage of coma. The diagnosis of cerebrospinal meningitis was at once made, but was altered to tuberculous meningitis when tubercle bacilli were found in the cerebrospinal fluid removed by lumbar puncture. A very unfavourable prognosis was given; but after the tenth day the patient steadily improved, and in three weeks was able to leave his bed. Three months later the man was well, though the optic neuritis which was present on admission persisted.

Henkel [29] published the case of a boy, aged 10, who suffered from meningitis with double optic neuritis. Lumbar puncture and an examination of the cerebrospinal fluid disclosed numbers of tubercle bacilli, thus proving the case to be tuberculous meningitis. The boy remained in a serious condition for twelve days, and then gradually improved; a month after the onset of the attack he was able to walk. As the boy at this period was unsteady on his feet and reeled to the right, it was thought that there might be a solitary tuberculous mass in the cerebellum; but all these symptoms disappeared within three weeks, and the boy was discharged without any trace of his illness.

Gross [26] records the case of a boy, aged 17, who had been struck on the head with a beer-bottle five days before he came under observation. The discovery of tubercle bacilli in the fluid withdrawn by lumbar puncture proved that the case was one of tuberculous meningitis and that the original diagnosis of serous meningitis was wrong. The boy gradually improved and made a perfect recovery from the meningeal disease, but twelve months after the onset of the meningitis he was found to have pulmonary tuberculosis. An interesting point in this case was that the differential count of the cell elements present in the cerebrospinal fluid, in exception to the general rule, showed a predominance of polymorphonuclear cells.

A very similar case is reported by Stark [53]. The diagnosis of enteric fever was at first made, as the patient, a man aged 44, was suffering from fever, vomiting, headache, diarrhœa, and retraction of the head. After four days, however, the appearance of ocular phenomena—viz., optic neuritis and inequality of pupils—together with a paresis of the face, showed that the disease was a meningitis. Lumbar puncture was performed, and tubercle bacilli were found in the cerebrospinal fluid. The patient recovered completely and increased some 3 lb. in weight while under observation.

Barth [4] again published the case of a girl, aged 32 months, in which the symptoms made him consider the possibility of tuberculous meningitis. As the disease progressed the symptoms became more characteristic, and the diagnosis was confirmed by the discovery of tubercle bacilli in the cerebrospinal fluid. Contrary to expectation, the child lived and, after an illness of six months' duration, was restored to health.

At the International Congress of Tuberculosis held in Washington, during 1908, Stiles [54] related two cases which showed the possibilities of surgical treatment in this affection. In both cases an operation was performed to relieve intracranial pressure, and in the fluid which escaped on opening the dura mater tubercle bacilli were found. The cases both recovered; in one a recurrence of symptoms followed the closure of the wound, but disappeared when the wound was reopened. Stiles stated that in his opinion many lives would be saved if the above surgical procedure were adopted more frequently.

The following is an abstract of a case reported by Alanzino [1]: The patient presented the clinical symptoms of tuberculous meningitis; the cerebrospinal fluid gave a cell deposit in which lymphocytes were greatly in excess, as is usual in this disease, and a guinea-pig inoculated with some of the fluid showed tuberculous lesions when killed on the fiftieth day. The child recovered and was in perfect health during the six months that he remained under observation.

Tedeschi [56] observed a case of recovery from tuberculous meningitis in a girl aged 14. The differential count of the cell-elements in the cerebrospinal fluid, together with the clinical symptoms, pointed to tuberculous meningitis, and this diagnosis was confirmed by the positive result obtained from the inoculation of a guinea-pig. The patient recovered and was helping her mother in household duties when last seen. Interesting points in this case were the absence of fever and of Kernig's sign during the illness, as well as the almost complete disappearance of the lymphocytosis present in the cerebrospinal fluid prior to her discharge from hospital.

A case is recorded by Jemma [33] in which a boy, aged 3½, suffered from an illness that was proved to be tuberculous meningitis by the clinical symptoms, the presence of a lymphocytosis in the cerebrospinal fluid, and the inoculation of a guinea-pig with a positive result. The convalescence was prolonged, but three years later the child was in good health.

Gareiso [23] records a case from the Argentine Republic of a boy,

aged 8, in whom the onset was slow and the symptoms typical. The cerebrospinal fluid on examination showed the lymphocytosis usual in tuberculous meningitis, and inoculation of a guinea-pig resulted in its death from tuberculosis. The child was quite well at the end of six months and continued in good health for at least twelve months after the onset of the attack.

Claisse and Abrami [12] showed a case of recovery before the Société Médicale des Hôpitaux de Paris. The onset of the illness in the patient, a man aged 30, was characteristic and was accompanied by fatigue, headache, loss of flesh, and insomnia. Later the patient suffered from delirium, accompanied by violent actions, ideas of persecution, anorexia, obstinate constipation; the pupils were unequal and reacted slowly to light. There was a lymphocytosis of the cerebrospinal fluid and a guinea-pig which was inoculated died of tuberculosis. The patient made a satisfactory recovery.

In a discussion which took place Montard-Martin, Sicard, and Achard mentioned cases under their care in which remissions had taken place, while Dufour stated that on two occasions he had made *post-mortem* examinations and had found cerebral and meningeal tubercles which were not of the same age.

At the next meeting of the same Society Vaquez and Digne [60] communicated a similar case of recovery from tuberculous meningitis. The clinical signs were most characteristic, and the diagnosis was confirmed by the examination of the cerebrospinal fluid, as well as by the positive result obtained from the inoculation of it into a guinea-pig. After recovery, instead of the large number previously present, the cerebrospinal fluid contained but few lymphocytes and no longer produced tuberculous lesions in guinea-pigs.

Vaquez and Digne considered that meningitis was undoubtedly present unless the clinical symptoms, as well as the macroscopic and microscopic character of the cerebrospinal fluid, were of no significance, and that the tuberculous nature of the meningitis was conclusively proved by the fact that the liquid withdrawn by lumbar puncture caused tuberculosis in a guinea-pig.

In a case recorded by Rossini [49] the tuberculous nature of the disease was demonstrated by the inoculation of a guinea-pig and the production of a generalized tuberculosis in the animal. There was complete recovery.

The case recorded by Janssen [31] was that of a soldier, aged 19, who, after an attack which was diagnosed as tuberculous meningitis,

recovered sufficiently to resume his military duties. Three years later the man died from phthisis after an illness of four months. *Post-mortem* examination revealed yellow caseous masses on either side of the superior longitudinal sinus, which on careful examination were found to consist of small round tubercles. Scattered tubercles, completely obsolete, were also found over the pia mater, especially along the course of the vessels and in the sulci between the convolutions. Similar obsolete tubercles were found around the optic chiasma at the base of the brain. Microscopical examination failed to disclose tubercle bacilli and indicated that the tubercles were of considerable age.

Janssen refers to cases of recovery from tuberculous meningitis which I have been unable to trace. Politzer observed a case in which death occurred in a relapse three years after the first attack. On *post-mortem* examination he found thick fibrous tissue over the base of the brain, which was evidently produced by the previous attack, and young disseminated tubercles in the pia-arachnoid. Schwalbe observed two cases in which recovery from tuberculous meningitis took place. The patients died later from diphtheria, and the diagnosis was then confirmed by the discovery of a meningeal tuberculosis not of recent date. Another case of recovery from tuberculous meningitis is reported by Carrington, in which diagnosis was confirmed by *post-mortem* examination as the patient died later from psoas abscess. Finally, Janssen refers to a paper by Leube, in which there is reported the case of a girl, aged 24, who presented signs of phthisis and of inflammation of the spinal meninges. The latter symptoms subsided, leaving only a few traces behind. The diagnosis of tuberculous spinal meningitis was later confirmed, as the girl died from generalized tuberculous meningitis, and *post-mortem* examination revealed an older tuberculous affection of the spinal meninges.

A case of recovery from tuberculous meningitis was published by Riebold [45]. A young girl, aged 6, presented all its symptoms; the diagnosis was placed beyond doubt by the discovery of numerous tubercle bacilli in the cerebrospinal fluid and the intraperitoneal inoculation of guinea-pigs, with as a result the production of typical generalized tuberculosis. The treatment of this case was lumbar puncture repeated daily until 574 c.c. of fluid had been withdrawn. After the early punctures improvement took place and the general condition gradually returned to normal. At the beginning of 1906, two months after the onset of the illness, the patient was considered out of danger, and when seen in August of the same year was in excellent health. The evidence

as to the tuberculous nature of the meningitis is in this case very conclusive.

Possibly the most interesting case of all is that recorded by Rumpel [50], who exhibited at the Aerztlicher Verein in Hamburg the brain of a boy, aged 17, who had died of phthisis. At the age of nine the lad had an acute attack of meningitis in which there was retraction of the head, hyperæsthesia, absence of the knee-jerks, bilateral optic neuritis, ptosis and, paralysis of the external recti. Lumbar puncture gave a fluid in which tubercle bacilli were found. The boy, who was treated by repeated lumbar punctures, recovered, and, though for some months he was dull and stupid, he eventually returned to his normal mental condition and was able to keep pace with others of his age at school, while all abnormal physical signs had disappeared. He remained about four years in good health, but then developed a tuberculous abscess in the axilla, which was followed by pulmonary tuberculosis; death took place eight years after the onset of his meningeal symptoms. At the *post-mortem* examination it was found that the membranes over the fissure of Sylvius on either side of the brain were thickened and glued together, but miliary tubercles were no longer visible. In this case not only was there confirmation of the diagnosis during life by the discovery of tubercle bacilli, but also a *post-mortem* examination in which the site of the old meningitis was discovered.

In the three cases which follow the observers record the discovery of tubercles in the choroid on ophthalmoscopic examination as a confirmation of the diagnosis of tuberculous meningitis.

In Lunn's [37] case the patient was a girl, aged 6, whose father had died from phthisis; she was admitted to the St. Marylebone Infirmary with symptoms resembling those of enteric fever. Six days after admission the symptoms became those of meningitis, and there was a blood-stained discharge from the left ear, which, however, soon ceased. On ophthalmoscopic examination optic neuritis was discovered in the eyes, and in the left a large white oval area about one-third the size of the optic disc was seen. This area appeared somewhat raised and was free from pigment, except for a fine line at the lower border. The retinal vessels passed over it. Two smaller patches were also noticed: the one, white in colour, was situated near the lower and outer edge of the large area; the other, of a greyish hue, was placed above the inferior temporal vessel. The eyes were examined by Lunn, Rayner-Batten, and Lawford, who agreed that tubercle of the choroid was present, and accordingly a diagnosis of tuberculous meningitis was made. Three

days later the child began to improve and recovery ensued. Before the child left the Infirmary the optic neuritis and one of the smaller patches had vanished. The large oval area was still present, and the small patch which remained was fading.

Although the symptoms in this case were not very conclusive, the presence of the optic neuritis and other cerebral symptoms makes the diagnosis of meningitis probable. The presence of tubercles of the choroid points to the meningeal disease being of a tuberculous nature.

Dujardin-Beaumetz [18] recorded a case in which the symptoms were at first supposed to be those of enteric fever, but gradually progressed until the typical appearance of tuberculous meningitis was present. The man, however, recovered and was discharged without any trace of the illness. Dujardin-Beaumetz, feeling sure of his diagnosis, had an examination made by an ophthalmic surgeon, who found in the right eye not only all the signs which are characteristic of tuberculous meningitis, but also a tubercle of the choroid, which he believed confirmed the diagnosis.

In Thomalla's [57] patient the parents were tuberculous, and the man himself suffered from rectal fistulæ of a tuberculous nature. The symptoms were those of tuberculous meningitis, and an ophthalmoscopic examination disclosed two absolutely typical recent tubercles in the choroid of the left eye. The patient made an excellent recovery, and three months after the onset of the attack the choroidal tubercles were found to have disappeared, leaving only a pigmented scar behind.

IV. Differential Diagnosis.

In the differential diagnosis of tubercular meningitis there must be taken into consideration that condition known as *meningism*, a term applied to the appearance of symptoms which simulate more or less closely those of meningitis in the course of infective illnesses and intoxications, but no morbid lesions can be found in the meninges after death; and *serous meningitis*. This condition, in which there is an exudation of serous fluid into the subarachnoid space, can also produce the symptoms of an infective meningitis; but the temperature is usually not as high as in true meningitis, and it soon returns to the normal, the headache is less severe, the retraction of the head is less marked, and the physical signs are only transitory. Optic neuritis is frequently present and the knee-jerks may be absent.

These conditions can be, however, distinguished from true meningitis by lumbar puncture, as the fluid, though often under great tension, is clear, contains an increased amount of albumin, but only a few cell elements and no micro-organisms.

Serous meningitis is usually due to some toxin circulating in the blood, and it is of interest in relation to our subject that many authors, as Münzer [39], Riebold [45], and Biedert [7] consider that the tubercular toxines occupy the most important place in its ætiology.

In addition to the clinical evidence of this we have the experimental work of Armand-Delille [2]. By the injection of extracts of toxins obtained from the tubercle bacillus into the subarachnoid space of the brain he was able to produce a diffuse infiltration of the pia mater with mononuclear and polymorphonuclear leucocytes, which in places tended to form nodules, in the centre of which caseation could be often observed; similar cells also infiltrated the perivascular spaces, and secondary changes were often observed in the adjacent nerve cells. In a later stage these changes were represented by a sclerosis of the pia-arachnoid. The lesions produced by the local action of tuberculous toxins thus resemble closely those of tuberculous meningitis.

Laignel-Lavastine [36] has also shown that pathological changes can be detected in the nerve cells of the cerebral cortex in general tuberculosis, even when there is no infection of the brain.

These clinical and experimental facts demonstrate that the tuberculous toxins can produce lesions both of the meninges and of the cerebral cortex apart from direct infection.

In *serous*, however, as distinguished from *infective* meningitis the exudation is caused solely by the action of toxins, and *micro-organisms cannot be found in the cerebrospinal fluid.*

From this fact it follows that the cases I have collected, in which the presence of tubercle bacilli has been demonstrated in the cerebrospinal fluid either microscopically or by inoculation, must be regarded as recoveries from true tuberculous meningitis; but in those cases in which the diagnosis has been based on the clinical aspect alone, or on this together with the presence of a lymphocytosis of the cerebrospinal fluid and a positive result given by tuberculin reactions, it is difficult to say whether there has been a serous or a true tuberculous meningitis.

It is well known that the progress of tuberculosis in other organs may be interrupted by periods of quiescence, or even by recovery. Apparently the resistance of the individual to the disease is an impor-

tant factor, and that this comes into play in tuberculous meningitis is evident from the course and duration of the disease in different individuals. Hall and Hopkins [28], for instance, found that the duration of the disease varied between three and ninety days in fifty-two cases which they observed.

Despite the clinical experience of many expert observers and the statements to the contrary contained in many medical text-books, it is therefore not irrational to consider the possibility that tuberculous meningitis, too, may terminate in recovery or in long periods of remission.

In the *post-mortem* examinations which have been made on patients in whom remissions or recoveries have occurred the earlier tuberculous lesions have been represented merely by a sclerosis of the meninges; we may consequently assume, in those cases which recover from tuberculous meningitis, either that the virulence of the bacilli has been so small that the lesion has had little or no tendency to become disseminated over the meninges, or that the resisting power of the patient has been so great that the tuberculous meningitis terminated at an early period of its existence.

The fact that a recurrence of the disease has taken place after many years (in Rilliet's [46] case five and a half years intervened between the attacks) proves that the localized form is a constant source of danger, and that the possibility of a recurrence must be always considered.

V. Treatment.

It is interesting to review the treatment adopted in the cases which recovered, or in which there was a long period of remission from active disease. I hoped to find some one method which might be considered as contributing largely to the successful termination, but this has not proved the case, for the methods of treatment adopted differ widely, and each physician attributes the fortunate termination to the particular method he employed.

Janssen [31] considered that the recovery of the patient under his care was due to enormous doses of iodide of potassium, 600 gr. a day being the amount administered. Barth [4], on the other hand, obtained no improvement with potassium iodide, baths and cold effusions to the head, but attributed the recovery in his case to the abstraction of blood by leeches applied over the mastoid processes for eight consecutive days.

Rumpel [50] and Riebold [45] believed that recovery in their respective cases was due to repeated lumbar puncture, which relieved tension and withdrew the toxins present in the cerebrospinal fluid. Stiles [54] strongly recommended operation with the same object in view. Finally, Rossini [49] considered the recovery of his case due to the injection of 1 oz. of a 1 per cent. solution of iodoform in almond oil into the subarachnoid-space every six hours, and every second day an intravenous injection of a 1 per cent. solution of iodine and potassium iodide.

As successful results have been obtained by methods which differ so widely, and as each of these methods has been tried repeatedly in other cases without success, the only safe conclusion is that the treatment employed had little or nothing to do with the recovery of the patients, and that the fortunate termination depended either on the increased resistance offered by the patients to the action of the tubercle bacilli, or on the small virulence of the bacilli themselves.

Finally, I must take this opportunity of expressing my thanks to Dr. F. E. Batten, who suggested this investigation to me and aided me in it with his advice and criticisms.

VI. Conclusions.

The conclusions to be drawn from the above facts are :—

(1) That undoubtedly long remissions and even recoveries do occur in tuberculous meningitis.

(2) That recoveries are possibly more frequent than has been believed, since no fewer than twenty undoubted cases have been recorded since 1894, while other cases of recovery have been published in which the same definite proof of the nature of the disease has not been afforded, but some of which probably were true cases of tuberculous meningitis.

(3) That in these cases either the resistance of the individual is so much greater than usual that the disease is checked early in its course, or the virulence of the bacilli is so much less than usual that the lesion in the meninges becomes localized and later undergoes a fibrous change.

(4) That the lesion in the meninges may at a later period form the focus of a fresh infection which usually terminates fatally, and that consequently the prognosis in these cases must be guarded.

(5) That no treatment up to the present has been discovered which has had any specific effect in promoting the favourable termination of the disease.

References.

[1] Alanzino. *Riformi med.*, 1903, Ann. xix, p. 936 (abs. *Rev. neurol.*, 1903).
[2] Armand-Delille. Thèse de Paris, 1903.
[3] Barlow, Sir Thomas. "Clifford Allbutt's System of Medicine," 1899. 1st ed., vol. vii., p. 481.
[4] Barth. *Münch. med. Wochenschr.*, 1902, Bd. xlix, S. 877.
[5] Bernstein. *Med. News*, 1905., vol. lxxxvi, p. 1105.
[6] *Idem. Mount Sinai Hosp. Reports*, 1907.
[7] Biedert (*cit.* Oppenheim).
[8] Buchanan. *Lancet*, 1907, vol. ii, p. 1764.
[9] Carles. *Arch. de Méd. des Enfants*, 1908, t. xi, p. 130.
[10] Carpenter. *Reports of the Soc. for the Study of Disease in Children*, 1902, vol. ii, p. 203.
[11] Carrière et Lhôte. *Rev. de Méd.*, 1905, t. xxv, p. 469.
[12] Claisse et Abrami. *Gaz. des Hôp.*, 1905, t. lxxviii, p. 667.
[13] Coulon. *Méd. enfantile*, 1894, t. i, p. 340 (*cit.* Carrière et Lhôte).
[14] Collins, E. Treacher. *The Ophthalmoscope*, 1907, vol. v, p. 2.
[15] Cruchet. *Rev. neurol.*, 1902, t. x, p. 1077.
[16] Don. *Brit. Med. Journ.*, 1907, vol. i, p. 1360.
[17] Dudon. *Mém. et Bull. de la Soc. de Méd. de Bordeaux*, 1876 (*cit.* Carrière et Lhôte).
[18] Dujardin-Beaumetz. *Bull. de la Soc. de Méd. des Hôp. de Paris*, 1878.
[19] Emery. "Clinical Bacteriology and Hæmatology," London, 1908.
[20] Forbes. *Quarterly Journ. of Med.*, 1908, vol. i, p. 109.
[21] *Idem. Lavori e Riviste di Chimica e Microscopia Clinica*, 1908., vol. i.
[22] Freyhan. *Deutsche med. Wochenschr.*, 1894, Bd. xx, S. 707.
[23] Gareiso. *Revista de la Soc. med. Argentina*, 1908 (abs. *Arch. de Méd. des Enfants*, 1908).
[24] Goggia. *Gaz. degli Ospedali e delle Clin.*, 1905, Ann. xxvi, p. 133 (abs. *Rev. neurol.*, 1905).
[25] Gowers. "A Manual of Diseases of the Nervous System," London, vol. ii.
[26] Gross. *Berliner klin. Wochenschr.*, 1902, Bd. xxxix, S. 776.
[27] Hahn (*cit.* Carrière et Lhôte).
[28] Hall and Hopkins. *Journ. Nerv. and Ment. Diseases*, 1906, vol. xxxiii, p. 242.
[29] Henkel. *Münch. med. Wochenschr.*, 1900, Bd. xlvii, S. 799.
[30] Hirschorn. Thèse de Paris, 1903.
[31] Janssen. *Deutsche med. Wochenschr.*, 1896, Bd. xxii, S. 169.
[33] Jemma. *La Pediatria*, 1907 (abs. *Rev. neurol.* 1908).
[34] Jessop. *St. Bartholomew's Hosp. Reports*, 1905, vol. xli, p. 183.
[35] Jirasek. *Rev. v. Neurologii*, 1904 (abs. *Rev. neurol.*, 1905).
[36] Laignel-Lavastine. *Rev. de Méd.*, 1906, t. xxvi, p. 270.
[37] Lunn. *Trans. Ophthalmol. Soc. London*, 1904, vol. xxiv, p. 127.
[38] Mermann. *Beiträge zur klin. Chirurg.*, 1902, Bd. xxxiv, S. 268.
[39] Münzer. *Prager med. Wochenschr.*, 1899, No 46.
[40] Mutzner. *Arch. gén. de Méd.*, 1901, t. clxxxviii, p. 345.
[41] Oppenheim. "Lehrbuch der Nervenkrankheiten," Wien, 5te Aufl., 1908.
[42] Ovazza. *Riforma med.*, 1906, vol. xxii, p. 964.
[43] Porot. *Rev. de Méd.*, 1908, t. xxviii, p. 37.
[44] Raw. *Lancet*, 1908, vol. i, p. 481.
[45] Riebold. *Münch. med. Wochenschr.*, 1906, Bd. liii, S. 1709.
[46] Rilliet. *Bull. de la Soc. de Méd. des Hôp. de Paris*, 1853 (*cit.* Carrière et Lhôte).
[47] Rocaz. *Arch. de Méd. des Enfants*, 1901, t. iv, p. 738.
[48] Rossi. *Gaz. degli Ospedali e delle Cliniche*, 1905, Ann. xxvi, p. 473.
[49] Rossini. *La Clinica mod.*, 1904, vol x, p. 445 (abs. *Rev. neurol.* 1905).
[50] Rumpel. *Deutsche med. Wochenschr.*, 1907, Bd. xxxiii, S. 2021.
[51] Saenger. *Neurol. Centralb.*, 1903, Bd. xxii, S. 794.

[52] SEPET. *Médecine mod.*, 1902, t. xiii, p. 225.
[53] STARK. *Neurol. Centralb.*, 1908, Bd. xxvii, S. 633.
[54] STILES. *Proc. Internat. Cong. of Tuberculosis*, Washington, 1908.
[55] TAYLOR, F. "Manual of the Practice of Medicine," London, 1908.
[56] TEDESCHI. *Gaz. degli Ospedali e delle Cliniche*, 1905, vol. xxvi, p. 1045 (abs. *Rev. neurol.*, 1906).
[57] THOMALLA. *Berliner klin. Wochenschr.*, 1902, Bd. xxxix, S. 565.
[58] TRIPIER. *Provence médicale*, 1902 (abs. *Rev. neurol.* 1903).
[59] TROISIER et BRULÉ. *Rev. neurol.*, 1907, t. xv, p 1135.
[60] VAQUEZ et DIGNE. *Gaz. des Hóp.*, 1905, t. lxxviii, p. 702.

Publications Recently Received.

[*Notes on a book under this heading do not preclude a subsequent review.*]

Arbeiten aus der deutschen psychiatrischen Universitäts-Klinik in Prag. Herausgegeben von Professor Dr. Arnold Pick. Mit zahlreichen Abbildungen im Text und 11 Tafeln, S. 143. Berlin: Karger, 1908.

One of the most interesting papers in this collection is that on a case where the knowledge of the position of parts of the body was gravely disturbed. The patient did not know where such parts as her ears, her eyes, her legs were to be found. Told to touch her nose, she could do so automatically; but if her hands were held for a moment, so that this automatic response was prevented, she searched in her lap and other parts of her body. A full abstract is given of Professor Pick's contribution to the Amsterdam Congress on asymboly and aphasia. Papers on tumours of the hypophysis, on the symptomatology produced by atrophy of the occipital lobes, on local senile atrophy of the brain, on the loss of cortical fibres in general paralysis, make up an interesting volume.

Ueber die Functionen von Hirn und Rückenmark. (Gesammelte Mitteilungen—Neue Folge.) Von Hermann Munk. Mit 4 Textfiguren, S. 371. Berlin: Hirschwald, 1909.

We welcome this reprint of the papers of Professor Munk on the functions of the cortex and the cerebellum. For when the dust of a controversy has died down it is well to look back on the documents to learn how the universal beliefs of to-day have been built up. A perusal of these papers shows how much we owe to Professor Munk and his insistence on the afferent basis of cortical disturbances.

Symptoms and their Interpretation. By James Mackenzie, M.D., M.R.C.P. Pp. 297. London: Shaw and Sons, 1909.

In this book, devoted mainly to a formal statement of his views on pain of visceral origin, the author brings his great practical experience of disease to bear

on symptoms arising from reflex irritation of the nervous system. First he deals with the nature of pain, and insists that the viscera are completely insensitive. The causes of referred pain are discussed, and a chapter is devoted to increased sensibility of the external body-wall which so frequently accompanies it. The author insists on the importance of recognising the contraction of muscles evoked reflexly by visceral pain, so often misinterpreted by physicians. He then passes to a detailed consideration of the pain produced by the affection of the several organs based in every case on his own observations. Finally, the author sums up in a general estimation of the value of symptoms. There is a full index, which greatly facilitates reference to the many symptoms dealt with in this work.

A Text-book of Experimental Psychology. By CHARLES S. MYERS, Lecturer in the University of Cambridge. With 66 figures and diagrams, pp. 432. London: Edwin Arnold, 1909.

This is a most valuable handbook, and worthily supplies a long-felt want. In each chapter the student is given a short and readable account of some psychological question from the experimental standpoint. Every chapter has an appendix, in which the technical details of the elucidatory experiments are clearly described. The book begins with cutaneous sensations, and passes on through the special senses to the consideration of reaction-time, memory, local signature, identity and difference. Time and rhythm, attention and feeling, are also dealt with. The author is to be congratulated on the clearness and brevity of his explanations, in spite of the extensive ground covered by this work.

Lezioni di Anatomia Clinica dei Centri Nervosi. Per G. MINGAZZINI. With many illustrations, pp. 638. Torino: Unione Tipografico-editrice torinese, 1908.

This book consists of a series of lectures on the anatomy and functions of the central nervous system. In each chapter a single theme is dealt with and the anatomy and the functions of the part described. Thus three chapters are devoted to the spinal cord, eleven to the mid-brain and cerebellum, and four to the cerebrum. The author deals with the aphasia, alexia, and agraphia, and a lecture is devoted to the relation of speech and thought. The book is profusely illustrated with diagrams.

The Medical Annual for 1909. Pp. 744. With many illustrations. Bristol: John Wright; and London: Simpkin, Marshall and Co., 1909.

This volume is in every way up to the standard of its predecessors. Few fresh methods of treatment have been introduced into neurological practice

during the last year, but the alcohol treatment of neuralgia receives full notice, and there is a good article on intracranial surgery. The illustrations are remarkably good.

Epilepsia. Revue internationale trimestrielle, consacrée à l'étude au point de vue pathologique, thérapeutique, social et juridique de l'Epilepsie et des Maladies nerveuses du même ordre. Sous le patronage de MM. W. BECHTEREW; O. BINSWANGER; J. HUGHLINGS JACKSON; L. LUCIANI; H. OBERSTEINER; F. RAYMOND; avec une Comité de la Rédaction. 1e Année, 2me Fasc. Avril—Juin, 1909. Amsterdam: Scheltema and Holkema.

This number contains papers by Binswanger, Allan McDougall, Donath, Muskens and Apelt. To each paper is appended a short summary in a second language.

Die Erkennung des Schwachsinns im Kindesalter. Von Professor Dr. TH. ZIEHEN. S. 32. Berlin: Karger, 1909.

This is an address to teachers and parents on the signs of mental defect in children. In simple language the abnormalities of the skull, the skeleton, and the general bodily development are shortly described, and the author then passes on to want of co-ordination and other similar defects. He then treats of mental defects, which he groups under the heading of memory, comprehension, and judgment. This pamphlet would form an excellent guide to anyone anxious to put before teachers the simple signs of defective mental development.

Grundriss der psychiatrischen Diagnostik. Von Professor Dr. RAECKE. Mit 11 Textfiguren. S. 146. Berlin: Hirschwald, 1908.

This little book, which can be carried in the pocket, gives the various methods of examining the insane. It is adapted for German patients, but some similar pocket-book of methods is sadly wanting in English, and might perhaps improve the note-taking in our asylums.

Neurological and Mental Diagnosis: a Manual of Methods. By L. PIERCE CLARK, M.D., and A. ROSS DIEFENDORF, M.D. Pp. 188. New York: The Macmillan Co., 1908.

In the first half of this book the methods of neurological examination are described in order. It contains nothing new, and some of the methods advised are unnecessarily slipshod. The second half is devoted to the methods of examination in mental disease, but the general scheme is too short even for a student. It is difficult to see how the glossary at the end could be of use to any but an asylum attendant.

Nervous and Mental Diseases for Students and Practitioners. By CHARLES S. POTTS, M.D. Second edition revised and enlarged. Illustrated with 133 engravings and 9 plates, pp. 570. London: Kimpton, 1908.

This is a small text-book on conventional lines. The symptoms which may occur in the course of any one disease are thrown together in a form so compact that the student can obtain no picture of the disease.

Writers of "Original Articles and Clinical Cases" are supplied free of charge with 50 copies reprinted in the form in which the paper stands in the pages of "Brain." If reprints are required in pamphlet form, with wrapper, title-page, &c., and re-numbered pages, they must be ordered, at the expense of the writers, from Messrs. BALE, SONS & DANIELSSON, Ltd., 83-91, Great Titchfield Street, London, W.

Members of the Neurological Section of the Royal Society of Medicine can obtain the Index of "Brain" for the Volumes I. to XXIII. inclusive, that is, from its commencement to the end of 1900, from Messrs. MACMILLAN & CO., Ltd., St. Martin's Street, London, W.C., at the price of 6s. 6d., post free.

To those who are not members of the Neurological Section of the Royal Society of Medicine the price is 8s. 6d. net, and the volume may be obtained through any bookseller.

EDITOR.